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Photograph by courtesy of E. F. Bigelow

The bees keep piling up the ends of cylinders and keep constantly pushing inside to scrape the cylinders thin

HOW HONEYBEES PRODUCE HONEYCOMB (See page 100)

Monel Metal

Points of Superiority of This New Natural Alloy in All Fields for Non-Corroding Steel

By Hugh R. Williams

WHEN the Canadian Pacific Railroad was constructed through the Province of Ontario, Canada, large ore deposits were opened up in the Sudbury district. This was in 1884 and in the same year intensive mining operations were commenced on what was then supposed to be simply unusually rich copper deposits. Mining operations had not progressed far, however, before it was discovered that the ores were as rich, or richer, in nickel as they were in copper. Instead of merely rich copper deposits, this more or less chance discovery had unearthed nickel and copper deposits that have had a marked influence on the industrial activities of the entire world and particularly of the North American continent. The unparalleled nickel industry of this country so originated. The nickel plating for which this continent was famous while Europe and the rest of the world still employed brass and copper for the numerous purposes for which nickel plated ware is now used almost exclusively, the nickel steels with which our steel makers revolutionized steel making for certain purposes, and a large demand for German silvers and special alloys were results directly traceable in large measure to the Canadian Pacific extension. These unexpected developments are matters of record, universally accepted, but they in themselves do not complete the story of the Sudbury ores. The story is first one of copper, then one of nickel and finally one of Monel metal.

The ores of the Sudbury district are basic igneous rock carrying sulphides of nickel and copper with pyrrthotite (magnetic pyrites) as constituents, the sulphides more or less segregated. The nickel and copper were easily separated by an electrolytic process on the Bessemer matte produced by the smelting of the ores. This was the universal procedure until about 1905, when a second important discovery was made. A third metal, a natural alloy, with distinctive and commercially valuable properties was secured from the copper-nickel ores.

An important demand existed for alloys of the German silver class, in which two of the chief ingredients are nickel and copper. These metals were synthetic alloys produced by mixing the reclaimed copper and nickel in certain proportions with a third metal, usually zinc, and frequently with a fourth, as in the cases of certain bearing metals and some of the special German silvers. It was an attempt to develop a metal to compete with this German silver that brought about the discovery of Monel metal.

The chief metal ingredients of the Sudbury ores being nickel and copper—two of the main ingredients of the synthetic German silvers—the attempt was a logical one, but the recombining of metals that had just been painstakingly separated must have seemed a highly inefficient procedure. The nickel and copper contents of the Bessemer matte did not agree in proportions with those of any of the commercial German silvers, it is true, but there must have appeared no good reason to question the value of a new metal with nickel and copper contents in other proportions, particularly as the resulting metal was a natural alloy and not a synthetic mixture.

Numerous unsuccessful attempts to smelt the Sudbury ores without disturbing the balance of the chief metal contents, nickel and copper, preceded the final success. In 1905, a roasting process was invented by which the sulphur content was driven off and a matte produced which, after refining to remove impurities, contained the full nickel and copper contents of the original ore in remarkably uniform proportions. The average composition of the metal thus formed is:

Nickel	67%
Copper	28%
Other elements	5%

The other elements are chiefly iron from the original ore and manganese, silicon and carbon introduced during the process of refining. This distinctive metal was named *Monel metal*. It was invented, discovered or evolved to compete with German silver.

Instead of developing into simply a serious competitor in the German silver alloy fields, however, it was at once found that Monel metal possessed distinctive properties that promised for it a far more extended and important field of usefulness. It possessed the strength of mild steel, and, on account of its high nickel content, resisted oxidation to a marked extent. It was found also to be practically impervious to acid fumes and the great majority of commercial acid and alkaline solutions so extensively employed in many industrial processes. It could be cast, forged and welded, and in many respects possessed properties not unlike those of steel, and without the limitations of the latter. So important did the non-corroding properties of the metal appear that they were accepted as the feature of most value. The substitute for German silver became an acid-resisiing and non-corroding metal of the highest class.

TABLE OF PHYSICAL PROPERTIES.

Melting Point	1,360°C. (2,480°F.)
Specific Gravity (Cast)	8.87
Weight Per Cu. In. (Cast)	0.319 lbs.
Weight Per Cu. In. (Rolled)	0.323 lbs.
Coefficient of expansion, (20°C.—100°C.)	0.00001375 per 1°C.
Electrical Resistivity, 256 Ohms per mil foot. (Temp. Coefficient)	0.0011 per 1°F.
Electrical Conductivity	4% (Copper 100%)
Heat Conductivity	1/15 that of Copper
Shrinkage	¼" per foot
Hardness Cast Material	20-23 (Shore Scleroscope)
Hardness Hot Rolled Rods	27 (Average Shore Scleroscope)
Hardness, Hot Rolled Rods	162 (Average Brinnell)
Modulus of Elasticity	22,000,000-23,000,000

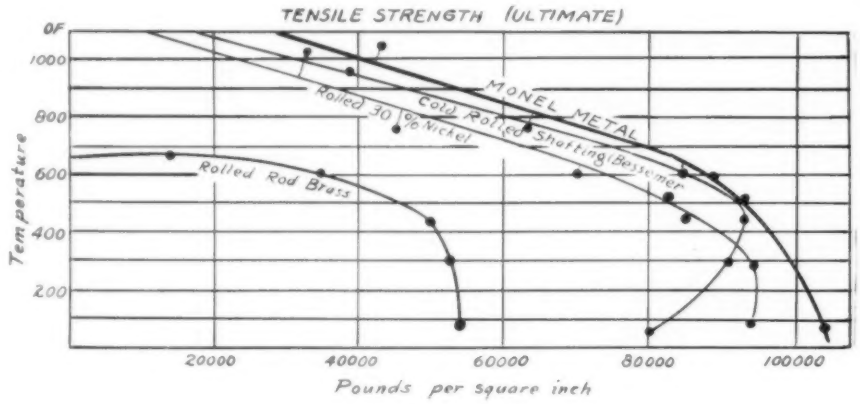


Fig. 1

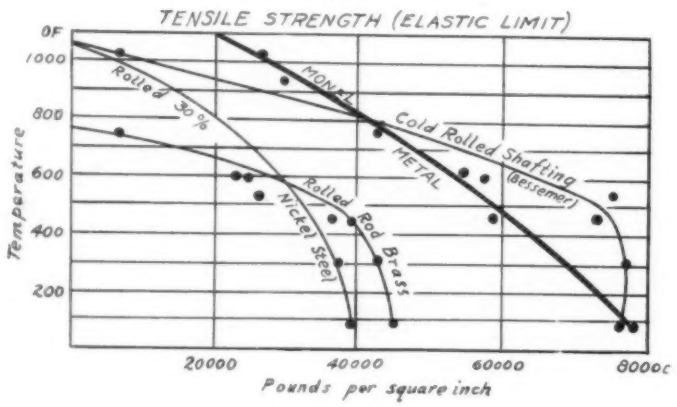


Fig. 2
Curves comparing the tensile strength of monel with other metals and alloys

TESTS ON RODS

TENSILE

Average representative tests of each of the three divisions as given:

	Yield Point Lbs. per Sq. in.	Ultimate Tensile Strength Lbs. per Sq. in.	Per cent Elongation in 2 in.
Up to 1 inch	63,126	94,562	40%
1 1/16 inches to and including 1 11/16 inches	61,963	93,104	39%
1¾ inches to and including 2 7/16 inches	50,115	87,678	42%
2½ inches to and including 3½ inches	43,805	85,282	44%
Over 3½ inches	47,335	84,763	43%
Rectangles	56,353	85,562	42%
Hexagons	60,736	87,781	40%

TORSIONAL (AVERAGE)

Shearing stress—Lbs. per sq. in. on remotest fibers:
At Elastic Limit 31,796
At Ultimate Load 79,053

COMPRESSION

Elastic Limit ..... 25,500 to 32,000 lbs. per sq. in.

TESTS ON CASTINGS

TENSILE

(Average of 172 Heats tested for Isthmian Canal Commission)

Yield Point	37,093 lbs. per sq. in.
Tensile Strength	72,281 lbs. per sq. in.
Elongation in 2 in.	34%
Reduction of Area	32%

COMPRESSION.

Elastic Limit ..... 12,000 to 25,500 lbs. per sq. in.

In 1906 a physical laboratory was established and intensive investigations commenced to ascertain conclusively the physical characteristics of the new metal and to disclose commercial fields for its use. The following year, fabrication problems on a commercial scale were undertaken, primarily to develop economic rolling processes for the fabrication of plates and sheets. The unusually high resistance of the metal to the corroding action of sea water and of the elements indicated an important market for ship plates and roofing of Monel metal.

Despite the extended experiments of 1907, the first commercial use to which Monel metal was put was in the form of castings. The U. S. S. *Dakota* was in the course of construction in 1908 and Monel metal propellers were cast for her at Bayonne, N. J. It was an unusual opportunity for Monel metal to establish a firm foothold in commercial activities. The battleship incorporated the latest developments in naval and ordnance constructions and then ranked with the best naval vessels of the day. The venture—for the adoption of propellers of a metal that had not as yet proved its superiority in any commercial undertaking of note was a venture—attracted widespread interest in industrial as well as naval circles. Doubtless, some viewed the experiment with misgiving, but the service rendered and the behavior of the propellers in operation were all that the most sanguine could have anticipated or wished. The resistance of the propellers to shock was extremely marked, yet their rigidity was equally pronounced, on account of the high modulus of elasticity of the metal. The propeller blades retained a high polished surface and showed unusual resistance to errosion at the high wheel speeds. These four desirable features were established during years in which the wheels were under the most critical investigation and inspection and substantiated all claims for the new metal—i. e., its non-corroding properties and its great strength.

During the latter part of 1908 and 1909, the second important commercial introduction of Monel metal was consummated. The Pennsylvania Railroad Terminal, New York, was roofed with Monel metal sheets. Here again Monel metal made an enviable reputation for serviceability, giving wonderful wearing service, excellent insulation against temperature changes—on account of the low heat conductivity of the metal—keeping the structure cool in summer and warm in winter, and virtually eliminating deterioration, leaks and repairs.

The success of the initial installation of ship propellers—those for the U. S. S. *Dakota*—brought tangible endorsement in 1910, for Montel metal propellers were in that year furnished for the U. S. S. *Florida*, a battleship of 21,825 tons displacement, just completed at a cost of nearly $6,500,000. Monel metal propellers were also installed on two battleships for the Argentine Republic and on a number of the United States destroyers. The following year saw a propeller cast for the Old Dominion Line and some wheels for the

Japanese Navy—each installation an unqualified success.

Coincidently with the Monel metal invasion of the marine propelling field, attention was focussed on another of the distinctive properties of Monel metal, viz., its similarity to steel in the matter of expansion and contraction under variation in temperature. This feature pointed to an important field of usefulness in steam service, particularly in superheated steam installations where the strength of steel was demanded for precaution against accidents, etc. Not only was Monel metal as strong as mild steel, but on account of the similarity of its coefficient of expansion it could be used in combination with steel in the form of bushings, disks and trim, with the assurance that the two metals would expand and contract as one, avoiding the danger of leakage, loosening of rings, etc., through expansion or distortion. The demand for a suitable metal for valve trim for cast steel valves, for steam turbine blading and for the many severe requirements of the power plant operating on superheated steam, was successfully met by Monel metal alone as all other available metals possess a sufficiently divergent coefficient of expansion to endanger property if used where tightness of closure and fit under all degrees of temperature are essential.

High-pressure cast steel valves for use in lines carrying high superheat were made feasible by Monel metal, on account of its coefficient of expansion. The development of the high pressure steam turbine was made possible by the resistance of Monel metal to the errosion of steam under high pressure and carrying superheat, as well as by the fact that other parts of the turbine could be constructed of steel, and accuracy of fit and alignment assured at all temperatures.

To the manufacturers of high pressure cast steel valves must be accorded the credit of discovering still another peculiarity of Monel metal. All metals lose a certain amount of their strength as their temperature is raised, and, as in high pressure steam service with superheat, temperature in the neighborhood of 800°F., are encountered, it is imperative that valve spindles, for instance, be proportioned for ample strength at such temperatures. To ascertain the influence of high temperatures on the strength of metals, the valve manufacturers conducted a series of comprehensive and exacting experiments, the results of which demonstrated the fact that Monel metal, in addition to being as strong as any known metal suitable for valve spindles at ordinary temperatures, resisted the weakening effect of high temperatures more successfully than any other metal. Monel metal proved stronger than 30 per cent. nickel steel at all temperatures, and at high, as well as normal, temperatures proved stronger than cold-rolled shafting (Bessemer). (See Fig. 1-3). At about 500°F., cold-rolled shafting has the peculiarity of attaining its maximum strength, and even at this temperature, Monel metal is somewhat the stronger. At the elastic limits of the various metals, Monel metal rods possess greater tensile strength than rods of any other metal at temperatures exceeding about 800°F. Below such temperature, the only metal rod showing superior tensile strength at its elastic limit was Bessemer cold-rolled shafting and this metal does not possess the non-corroding and acid-resisting qualities of Monel metal. Under torsion, Monel metal rods proved even stronger than bars of vanadium tool steel at temperatures in excess of 600°F., and at all temperatures proved stronger than nickel steel, any of the bronzes, cold rolled shafting, machinery steel, etc. (See Fig. 3.)

The non-corroding and acid-resisting metal, German silver substitute, proved pre-eminently superior to any other metal for superheated steam and elevated temperature service. Monel metal, chameleon-like, became something else, but, unlike the chameleon, retained all its former characteristics. Whether additional virtues will be discovered remains to be seen, but the distinctive properties of Monel metal have already opened up diverse and extended fields of usefulness for its application, and promise an ever increasing demand.

MONEL METAL CASTINGS.

In the shape of castings—to take up first that form in which Monel metal was first used commercially—there is scarcely an industry that does not now offer an important demand, in the interests of durability and true economy. From the large ship propellers and equally mighty water wheels of the hydro-electric power stations to golf-club heads is a long leap, yet Monel metal fills the bill in each case as well as for every commercial demand in the long range between, where strong, durable and dependable castings are essential—durable and dependable in that they must resist deterioration of all kinds and be of a lasting elasticity under any and all conditions.

As examples of the diverse uses to which Monel metal is put, here are a few. For the hardware of bank vaults, safes and treasure chambers—bolts, hinges, locks and ornamental trim—Monel metal castings are pre-eminently desirable, on account of their non-corrodability, unusual strength, handsome appearance—resembling burnished nickel—and dependability. In the dye house, casting parts of all equipment coming in contact with chemicals should advisably be of this metal, thereby avoiding heavy replacement expenses and serious depreciation.

In the power plant, the particular appeal of Monel metal castings is their distinctive properties of expansion and their resistence to the weakening influence of elevated temperatures, besides their qualities of resisting corrosion and oxidation and their great strength. Valve and valve trim, pump liners, bushing and glands, besides other castings subjected to the influence of superheated steam—particularly if forming a part of a steel casting—should be, to assure economic, efficient and safe steam power generation, of Monel metal.

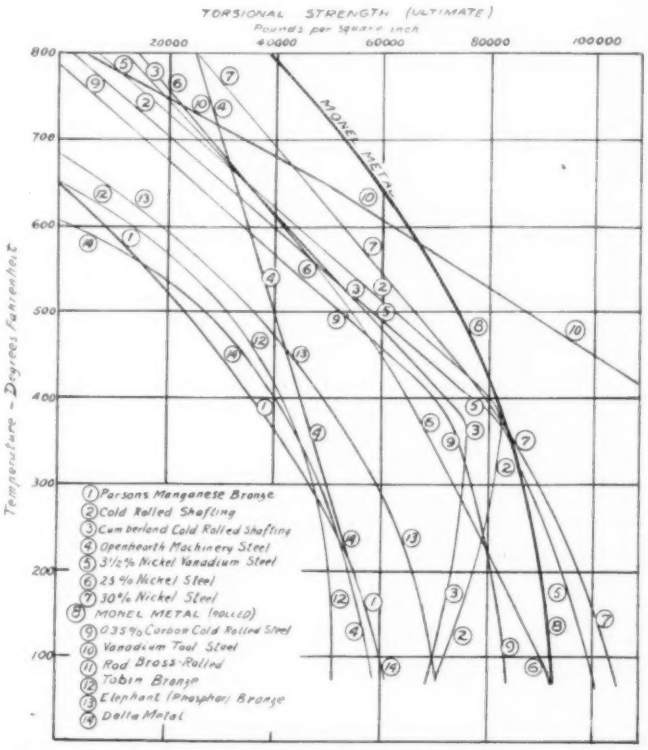


Fig. 3. Graphic comparison of torsional strength of monel and other alloys

Packing houses and refrigerating plants require the metal for pump liners and parts coming in contact with salt and brine. Steel mills need it for pickling crates and frames, valve and pump parts, etc., etc. Chemical plants use Monel metal castings for vats and pots, pump parts and hardware. Oil refineries use great quantities of Monel metal plugs for Burton stills, for pump liners, meter parts and much hardware.

In the marine field, deck fittings, shaft sleeves, stern bushings, rudder struts, stuffing boxes, pump liners are cast of Monel metal and in the engine room as many uses are found as in the stationary power plant. The ship propellers are simply individual applications, important as they are. Automobile fittings, levers, grip handles, and a variety of other parts swell the demand. Underground transit also offers an important field, cable racks, locks and man hole covers, in particular. Railroads, ships, and, in fact, in every type of transportation equipment Monel metal castings find a constantly increasing demand.

Even the dairy industry has sent out a call for Monel metal castings. Much of the equipment employed, such as milking machines, separators, pasteurizers, butter handling devices, etc., must be non-corroding, easily cleaned and of unusual wear-resisting character. Slicing machinery for food products must likewise be non-corroding, so for the casing, slicing and grinding parts of such equipment Monel metal again fills the bill.

The low heat conductivity of the metal, coupled with its resistance to the corroding effects of salt and brine, makes it particularly suitable for use in refrigerating and ice-making plants.

Instances of uses where the resistance of the metal to elevated temperatures is the main consideration are ignition chambers of gas and oil engines and in glass manufacture, for the parts coming in contact with the hot gases.

As for golf-club heads, nothing could be more suitable and all around desirable than Monel metal castings. The reason for this particular adaptability is readily apparent. In a golf club the balance is the chief consideration. Expert and novice alike lays particular stress on unchanging balance of his golf club. If the heads are of Monel metal the balance will always be the same, for the Monel metal heads will not rust, thus obviating that continuous grinding necessary when other metals are used. Besides this, the resilience of the metal is just right for a clean get-away.

Formidable as is the list of uses just referred to for which Monel metal castings are pre-eminently superior, the itemization merely touches some of the more obvious fields. The list indicates, however, the wide and varying uses for the metal and certain purposes for which modern requirements make it an essential.

MONEL METAL RODS.

The field for Monel metal rods embraces all those for castings, for seldom is a casting required that does not require screws, bolts, nuts, studs, tripods or struts of the same metal. In addition, pump rods, valve spindles, steam turbine blading, pickling pins, numerous kinds of tie rods, struts, ferrules and tubes are manufactured from Monel metal rods, because of their high tensile strength, non-corroding quality and resistence to errosion and to the weakening influence of elevated temperatures.

Ball bearings, numerous small parts of meters and even cutlery—knife blades, forks, spoons and novelties—are fabricated from Monel metal rods. An extensive and important use is for scale beams and lever rods for balance weighing scales, for the strength and non-corroding qualities of the metal are particularly desirable where accurate balance of parts is essential.

MONEL METAL SHEETS.

The original use of Monel metal sheets, for roofing, flashing, gutters, cornice work and the numerous other uses to which the metal is put in the building trade, does not by any means limit the field of usefulness developed during more recent years. The lining of tanks and vats for pickling processes, in dye works for linings to drying machines as well, and for laundry equipment to resist corrosive actions of soaps and acids, etc., are important fields.

Equipment and containers used for dairy and other food products are constructed in whole or in part of Monel metal sheets, as are sausage table tops in packing houses, for reasons of cleanliness, hygiene and sanitation. Kitchens and restaurants likewise offer many opportunities for profitable adaptation of Monel metal sheets, even a partial list of miscellaneous uses from airplane parts to identification tags and bar fixtures to automobile trim and battery casings are so numerous that no attempt can be made even to classify the fields, let alone itemize the various applications of the metal.

WIRE AND WIRE RODS.

Not only are Monel metal wire and wire rods important forms of this German silver—non-corroding—acid-resisting—high-temperature metal for light tie rods, struts and automatic screw machine products, but in building hardware, in particular, their essential uses are marked and varied. Sash cord that will not rust, corrode or break; window screens that admit more light and air and will not rust through or deteriorate; wire cloth, netting and screens for various purposes; office furniture and trim; escutcheon pins, tacks, rivets and considerable plumbing equipment may be mentioned.

As resistance wire in electrical equipment, such as in low temperature car heaters, etc., the high electrical resistance of the metal—if cost of maintenance is given due consideration—gives the wire an almost undisputed field. For gas and oil engines where high temperatures are encountered, Monel metal wire is employed for engine ignitions, needle valves on carburetors, spark plug electrodes and many other purposes.

Monel metal, although unlike any other metal, still possesses the valuable features of several.

How Honeybees Produce Honeycomb—I*

From Nectar the Bees Make Both Honey and Wax, from Wax They Build Cylinders to Hold the Honey

By Edward F. Bigelow, ArcAdiA, Sound Beach, Conn.

[Photographs made and furnished by the author; cuts 1 to 5 loaned by U. S. Department of Agriculture]

HONEYBEES gather principally two kinds of material —nectar and pollen. They also gather gum, the sticky exudation of buds, etc. This is called propolis and is for coating over the inside of the hive, filling cracks, etc. It is also mixed with wax to strengthen the comb, and applied to cells for "varnishing" and strengthening. The chief material for the building of the comb and for the honey is the nectar from the nectaries of flowers. Pollen, that well-known mealy material from the stamens of flowers, is used for the more solid food for the larval honeybees, on practically the same principle observed when other larvæ feed on

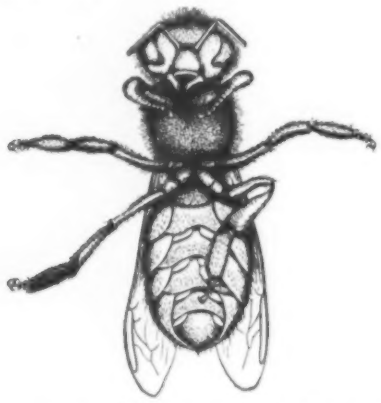


Fig. 2. Ventral view of a worker bee in the act of removing a wax scale. The two middle legs and the right hind leg are used for support, while the left hind leg removes the scale.

the solid parts of plants, as, for example, common tent caterpillars on leaves.

It is well known that the caterpillars of moths and of butterflies feed on leaves, while the adults sip only a little nectar from the flower nectaries. So it is with the honeybee. A large part of the diet of the growing bee in its larval or caterpillar stage, is the solid part of the plant, of which it selects the most refined portion, the pollen. Nectar is transformed into honeycomb for the protection of the eggs of larval and pupal forms, and for storing the honey.

When the honeybee is to transform the nectar into honey it takes the nectar into its honey sac, carries it to the hive and regurgitates it into the cell. When the nectar is to be transformed into comb it is swallowed and passed on beyond the stomach sac, through what is

Fig. 4. Ventral view of a worker bee showing the position of the wax scale just before it is grasped by the forelegs and mandibles. The scale is still adhering to the spines of the pollen combs. The bee is supported upon the two middle legs and upon the hind leg which is not removing the scale.

known as the stomach mouth. The nectar then goes through the processes of digestion, and enters the blood or the body fluid analogous with the blood, for the nourishment of the bee. But as is well known, from blood other products may be obtained by the action of certain glands, as, for example, milk. The honeybee obtains comb wax from its blood by the action of certain wax glands. These are eight in number and are situated on the lower side of the abdomen. From a recently hived swarm, bees may be obtained that will show thin films of pure wax somewhat resembling mica scales, and projecting for a microscopical distance from between the abdominal plates. It is an expensive product, demanding much food, and taxing to the extreme the bee's vital energy. The original estimate was that the bee must eat twenty pounds of honey to produce one pound of wax, but more recent investigators are inclined to lower the estimate, although some investigators still call for fifteen pounds. The secretion from these wax glands is in liquid form that by the action of the atmosphere soon hardens. The wax is then extremely brittle, and not adapted directly

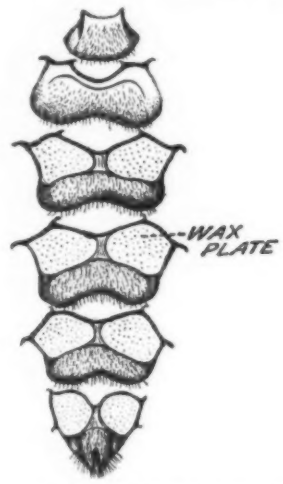


Fig. 1. Ventral abdominal plates of a worker bee dissected to show the position of the wax plates.

to the making of comb. It must be thoroughly worked over by the honeybee's mandibles.

Until about two years ago it was not known exactly how these scales are withdrawn from between the abdominal plates. Some observers asserted that they are scattered on the bottom of the hive, and collected by other bees as they might collect material outside of the hive. Other observers taught that the wax is passed from a wax producing bee to another bee that then molds it with her mandibles. About two years

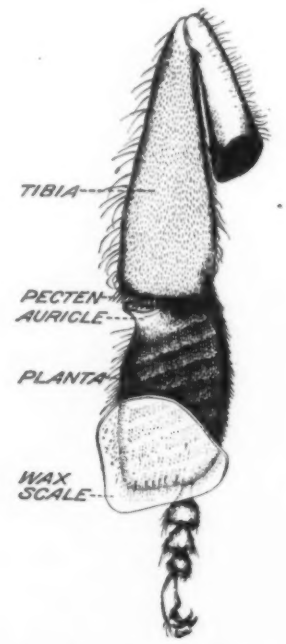


Fig. 6. Inner surface of the left hind leg of a worker bee, showing the position of a wax scale immediately after it has been removed from the wax pocket. The scale has been pierced by seven of the spines of the pollen combs of the first tarsal segment or planta. The jaws of the so-called wax shears or pincers are formed by the pecten spines above and the surface of the auricle below.

ago the Bureau of Entomology, Washington, D. C., published a remarkable circular to record the original investigations of Dr. D. B. Casteel, entitled "The Manipulation of the Wax Scales of the Honey Bee."

The workers never assist one another in the process of removal. The scales are extracted by the bee that secretes them, and by this bee they are usually masticated and added to the comb. The bee removes them while she stands on the comb or on its support. One of the hind legs is raised, and its flattened portion, known as the planta, is pushed along the underside of the extended abdomen until it come in contact with a scale protruding on that side. Steady pressure is now exerted against the abdomen and toward the rear. The result is that the scale is drawn out of its pocket and remains attached to the sharp, bristle-like hairs on the leg. This hind leg, now bearing the scale, is quickly bent forward toward the head, and the scale is

Fig. 3. Side view of a worker in the same posture as that shown in figure 2.

grasped by the fore legs, or by the mandibles. Sometimes it is aparently removed from the hind leg by the mandibles alone, but usually the fore legs aid in the process, and also manipulate the scale while the mandibles masticate it. After the scale has been thoroughly treated, the wax is applied to the comb. It is difficult to capture a bee just as the scale has been impaled by the tiny spines at the end of the leg, but the experimenter was in a few cases successful in doing so, and found that the scale had been pierced in several places by the strong spines that project from the lower rows of the pollen combs of the leg, as shown in the illustration. Regarding the scales that have been accidentally dropped Casteel writes as follows:

"In any hive where comb is being constructed rapidly many free scales will be found upon the bottom board and upon the lower bars of the frames. If these scales are examined microscopically some will be found without marks upon them, having evidently been loosened from their pockets accidentally during the movements of the workers over the comb and around the hive. Others will show certain marks and scratches upon them, indicating that they were voluntarily removed from the pockets, and in some cases

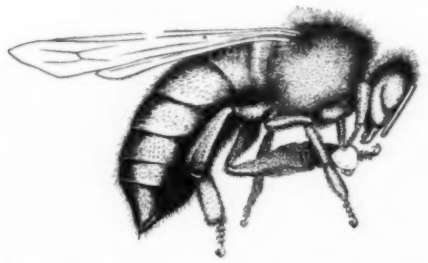


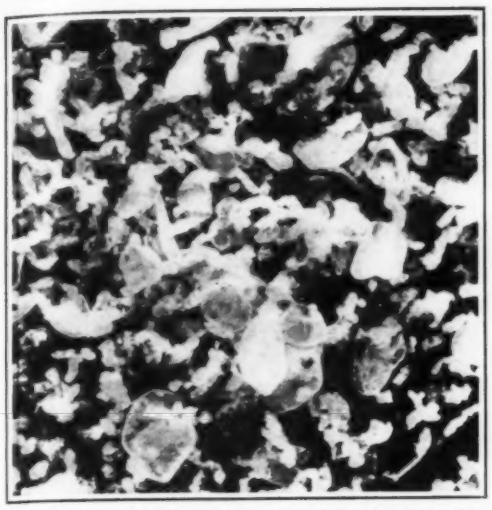
Fig. 5. Side view of a worker bee in the same posture as that shown in figure 4.

they may bear the marks of the mandibles, showing that they were dropped during the process of mastication. Most of the scales which are marked at all are indented with several small punctures showing the places where the spines of the pollen combs have pierced them. These scars are exactly similar in appearance to those on the scale shown in the illustration.

* * *

"As a rule the wax which is deposited upon the comb by the producing bee is first subjected to the action of the mandibles and mixed with saliva. Such, however, is not always the case, for some bees appear to be 'careless' and will mingle small unchewed portions of scales with the masticated wax. Indeed, it is not uncommon to find nearly perfect scales mixed with the wax of a newly made comb. The masticated wax itself is spongy and flaky when it is deposited by the

*Reprinted by permission from *The Guide to Nature.*



Wax flakes and "chips" from the bottom of the hive, dropped by the workers

producing bee and will later be reworked, thereby gaining greatly in compactness and smoothness.

"The entire process of the removal of one scale, its mastication, and the application of the wax to the comb is completed in about four minutes, only a very small portion of this interval being consumed in the work of extracting the scale from its pocket and passing it to the mouth, except in cases in which scales appear to be removed with difficulty.

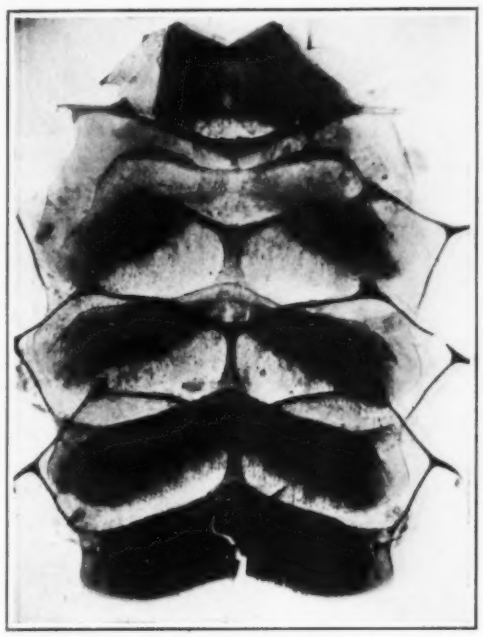
* * *

"Scales which drop are likely to remain for a long time, and some may even be carried out through the entrance with waste material. If, however, scales accidentally dislodged or voluntarily removed fall on the comb among the comb workers they are often noticed by them, picked up, masticated, and built into the comb. If a scale slips from the pollen combs or is fumbled by the bee before being grasped by the mandibles, it is seldom recovered by the worker to which it belongs unless it falls very near her or she stumbles upon it accidentally."

MY THESIS.

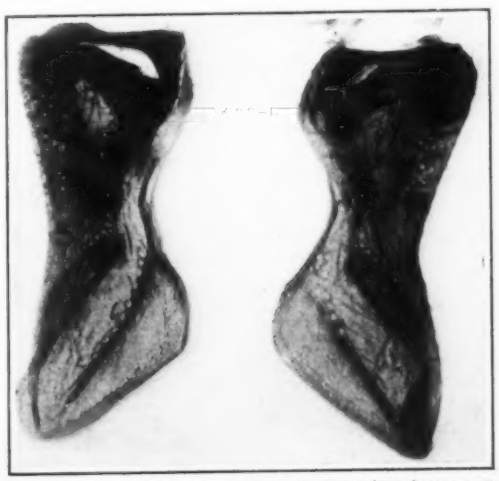
In my positive assertions, it is but fair to the general reader to state that many expert beekeepers do not agree with me. My claims have even brought ridicule from some; others have advised that I investigate further before publishing. This article is the result of about six years of study, and I publish it to bring out definite approval or objections as guidance in further study. I seek merely the truth, not victory of claim or argument.—E. F. B.

In making the comb, the honeybees never work in



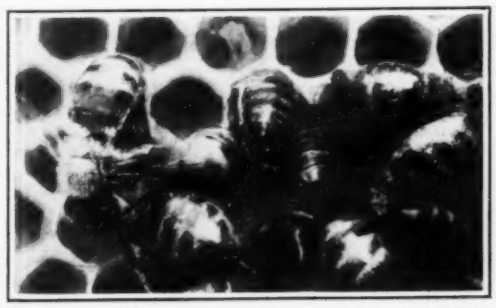
Photomicrograph of a bee's abdominal ventral wax plates that produce the wax scales

hexagons, but always in circles. Poets and philosophers have for ages expressed admiration for the wonderful skill of the bee in making angles and perfect hexagons in their comb cells. There are two errors in such commendations. First, the bee does not voluntarily make hexagons. The hexagons are the result of physical laws. They have nothing to do with the



Jaws of honeybee that work the wax flakes into honeycomb

"intent" of the bee, nor has the intent of the bee anything to do with them. Secondly, they are not perfect. Careful measurement of the various cells has shown that there is variation, due to difference in the size of adjoining cells. At one time it was thought that there could be no better standard of measurement than these hexagons. Naturalists have studied and argued as to how the bees have learned to make them. Even so careful a naturalist as Darwin in his interesting chapter, "Cell-making Instinct of the Hive-Bee," tries to



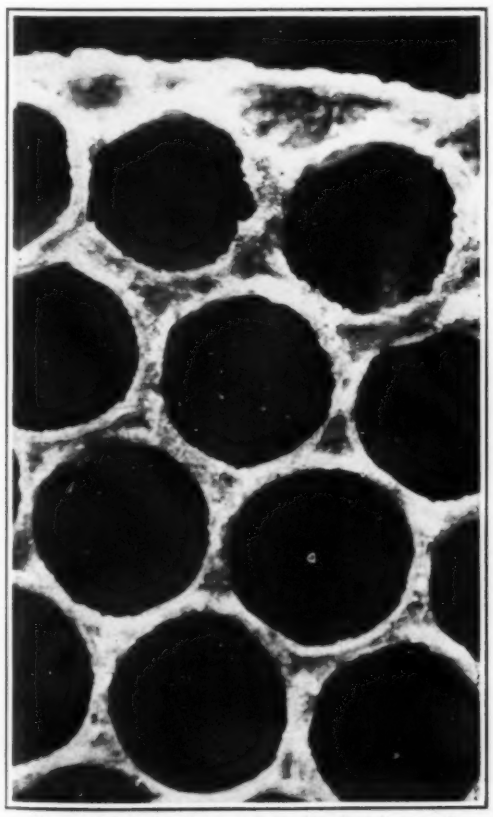
Like huge warm gun swabs, the crowded bees press in to clean the cells

prove his theory of special selection by teaching that the bee has learned through the influence of her environment. He admits that the bee makes a rough, circumferential wall or rim all around the comb, and then he tries to explain how the bee has learned to make the hexagons. The honey-bee deserves not one particle of credit for making a beautiful hexagon. All

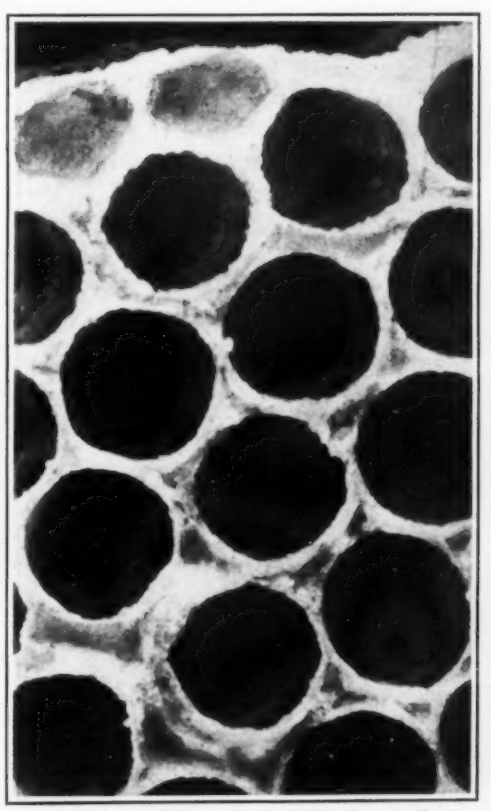
Wax flakes isolated from most of the "chips"

she does is to make a cylinder of wax, and a mighty crude one at that. Bees in series—that is, one after another—take the little plates of wax secreted from between the body scales and pack them into circles as crude as a child would make when she makes her mud pies. Under the microscope there is here no symmetry nor beauty, but only the crudest kind of work. The bee heaps up these pellets one after another, and the action of a physical law, and that action only, does the rest. She is as little responsible for the hexagonal form as she is for the movements of a planet. Both are under control of physical laws totally separate and distinct from any animal organism. For a lifetime, I may have watched that planet on every clear night when it is visible above the horizon, and I may repeatedly have observed that it moves, but I shall never learn how to make it move, nor shall I ever take to myself any credit for its movement. Through unthinkable ages honeybees have been making crude cylinders of wax, but they never yet have been able to make a hexagon nor to learn how to make one, Darwin and a host of minor lights, chiefly the utilitarian beekeepers, to the contrary notwithstanding. In making this statement I claim no originality. Long ago Cheshire, and Cowan said practically the same thing, but somehow their statements seem to flee from our modern thought of the honeycomb. Cheshire says, "All nature apart from the mystery of life solves everything mathematically. The cricket ball flying from the bat of the tyro, the spray from the maiden's mop, the tiny soap-bubbles of the laundress's lather, as much conform to perfect mathematical solution as the path of a comet or the form of a star."

(To be concluded)



Honeycomb in building. All the bee does is to make a mighty crude cylinder of wax



Honeycomb in building: Crude circles of wax. Not one hexagon has yet been found

Evolution and Sexuality*

Result of Former and Persisting Reaction Between Organism and External Conditions

By Etienne Rabaud, University of Paris

As a general rule the problems involved in the question of sex appear to have been rather inadequately stated. Morphological prejudices have dominated the subject of a phenomenon essentially physiological in its nature. When a question arises of the origins or of the consequences of the condition of sex, the dimorphism of the sexual elements and of sexual individuals attracts the attention of biologists far more than the physico-chemical differentiation from which this dimorphism results. Very often, indeed, this differentiation passes entirely unperceived. Following in the footsteps of Minot many authorities have believed that sex is derived from a doubling of an initial hermaphroditism. But such an hypothesis is based upon an evident confusion of ideas, since hermaphroditism, i. e., the reunion in a single individual of male and female gametes, is indisputably itself a form of sexuality and not at all the absence of all sexual differentiation. It is, in fact, the state of non-differentiation which is manifestly the initial state and this state still exists in the great majority of bacteria, which multiply exclusively by scissiparity, i. e. division, without any previous coupling. This mode of reproduction must necessarily have preceded the sexed condition. What then, we must inquire, is the origin of the latter and what its nature? Does it depend upon the organism itself alone? Or does it depend upon the interaction between the organism and the physical conditions of the latter's environment? And what, finally, are its consequences?

THE GENESIS AND NATURE OF SEX.

It cannot be doubted that sex is physico-chemical in nature; nevertheless, it is impossible to accept the assertions of those authorities who, following the lines indicated by Ralph (1884), pretend that the female is an individual which assimilates more than it disassimilates, i. e. which is anabolic and that the male is an individual which disassimilates more than it assimilates, i. e. which is catabolic—in other words an individual which is ill-nourished and always hungry. Most assuredly nothing could be more false than this idea; to convince ourselves of this we need only examine the phenomena of sex in those organisms which are anatomically the most simple, among others the Myxomycetes (slime fungi) and the Mucorinæ (mold fungi). In these fungi there exist two categories of individuals which closely resemble each other in external aspect, but each of which corresponds to a different physiological state. So long as the individuals in one category are separated from those in the other, they neither couple nor fructify; but so soon as they are reunited in the same culture medium the individuals of the one category unite with those of the other and bear fruit. Hence, the differentiation in sex is distinctly marked, though it is not revealed by any external sign; the general conditions of the metabolism appear to be very closely analogued. The sexuality does not correspond to any difference of this sort; the Mucorinæ even lose all sexual differentiation when one cultivates them in an exhausted medium. The conjugation of the Infusoria gives an indication along the same line; it is effected in fact between individuals which are morphologically comparable, both being large and visibly anabolic, or both being lean and visibly catabolic.

We must confine ourselves, therefore, to the determination of a differentiation such that individuals belonging to the same species and issuing from the same parents lose the property of being able to reproduce themselves without the assistance of each other. Does this differentiation correspond to the separation of a right substance from a left substance as Le Dantec has suggested? As to this we are entirely ignorant. But we know quite certainly that it corresponds to a chemical process. Cl. Vaney and F. Maignon (1909) observed in their studies of the silkworm that the metabolism of the females is distinct from that of the males, being already quite perceptible in the mature caterpillars. The males contain about four times as much fat as the females; in the former the quantity increases up to the time of opening, while it continues to diminish in the latter. The females, on the other hand, contain from three to nine times as much glycogen which they regularly consume until the time of opening, while the males continue to consume it after the opening. G. Smith (1915) likewise found differences corresponding to the sexes in the Daphnia (water fleas) and in the crabs with regard to the content of fat and of glycogen. Previous to this L. Hugonenq (1904) had found that the eggs of the Herring contain an albuminoid which is slightly acid and of complex chemical constitution, while the spermatozoids contain a protamine in which a very basic element predominates. Sprecher established the fact (1913) that the osmotic pressure of the hemp and of the sorrel is higher in the male than in the female at the moment of flowering and passes through a maximum in the female at the moment of the maturing of the seeds. These differences reveal an anabolism which is peculiar to each of the sexes.

It may be pretended evidently, as many authorities have done, that these differences are the result of the sexuality and not one of its conditions. But there is nothing to support this affirmation except the aspects of the nucleus of the sexual element whose origin remains uncertain and whose value is disputable. A considerable number of data, on the contrary, lead us to think that the sexual differentiation is derived from a previous differentiation of the anabolic metabolism under the influence of the conditions of the environment. In a renewed medium Woodruff obtained (1914) no less than forty-five hundred generations of the Infusoria (Paramecia) produced by simple division without the slightest appearance of sexuality. Jennings and Calkins had previously obtained a similar result; but after the lapse of a certain time the Infusoria were conjugated in couples although there had been no experimental intervention. From this the experimenters concluded that there was an alternation of sexed and non-sexed generations and that while possibly the alternation might not imply a definite number of generations, yet it was inevitably produced, the influence of the medium being confined to the prolongation or shortening of each period. The experiments of Woodruff, however, contradicted this interpretation; for not only was he able to prolong indefinitely the period of a sexual reproduction but he was able to determine at will the appearance and the disappearance of sexed generations. All that was required for his purpose was to leave the paranecia in a non-renewed medium or else place them in a renewed medium. Baitsell made experiments (1914) upon three other species of Infusoria with similar results. Stylonichia, for example, when raised in beef bouillon multiply without conjugating while they conjugate when placed in an hay infusion. Collin determined at will (1912) the conjugation of acinetic Infusoria by abruptly modifying the culture medium.

In consequence of these experiments it is rather difficult to believe in the existence and necessary appearance of a predetermined sexuality. We must conclude simply, that the Infusoria multiply with or without conjugation according to conditions. This forces another conclusion upon us, namely, that given these organisms we can occasion by means of certain external influences a differentiation between different individuals, such that they attract each other two by two and mingle their substance either definitely or not. There can be no doubt, moreover, that the general processes of nutrition constantly modify the organism. This modification is sometimes revealed in a visible manner, even in the Infusoria. Thus Woodruff observed a periodical remolding (refonte) of the nuclear apparatus; it seems probable that this may correspond to the periods of conjugation which are pronounced under certain conditions and in the course of which a very similar remolding is to be observed. The authorities agree in considering this remolding as the result of the coupling, but in our opinion it is probably merely a concomitant process.

These results, furthermore, hold good elsewhere than among the Infusoria. Besides the classic case of the plant-lice, which multiply indefinitely by an a-sexual method if external conditions are suitable, similar experiments have been made by Moro (1915) and Whitney (1914-1916) with Rotifera; and by Agar (1914) and Benta (1914) with Cladocera. By controlling and making more precise the earlier experiments of Maupas, these authorities proved that the parthenogenesis continues indefinitely under certain conditions and that the production of sexed generations corresponds to other conditions. Neither temperature nor inanition intervene in virtue of themselves, contrary to the belief of Maupas, but neither is there any cycle due to some internal factor as was thought by Woltereck and some of his followers, G. Smith in particular. The phenomenon is dominated by conditions of nutrition, which are, moreover, very complex. A simple modification of the temperature sometimes establishes a milieu which is favorable, either to parthenogenesis or to sexuality; however, it establishes such a favorable medium in a purely indirect manner, either by activating or retarding the cultures of Protozoa which serve as food for the animals experimented upon. Thus, according to Whitney, a moderate diet produces parthenogenesis in the *Chlamydomonas* while a more plentiful diet causes the production of males and females.

From all these experiments the influence of the milieu in the production of sexual differentiation becomes plainly evident. Is it not possible, furthermore, to make a comparison between these experiments and the facts relating to the cycle of development of various parasites which are reproduced by the sexual method in one host and the a-sexual method in another host? Further experiments, moreover, prove that external influences are capable of modifying the sex of organisms which differ greatly. Klebs (1899) by furnishing a Saprolegnium (a parasitic fungus) with very nutritive and frequently renewed aliments obtained a vegetative form which multiplied abundantly without reproductive elements; he obtained a monœcious form by cultivating this fungus in a solution of leucine and potassium phosphate and obtained female forms alone in a solution of hemoglobin. Van Thiegem had previously obtained similar results with Mucorineæ. Since then Perrin (1908) following after Prantl succeeded in modifying the sex of the prothalla of ferns in function of external conditions, and the same thing has been done with the prothalla of the Equisetacnæ (horse tail). Other investigators Molliard (1897), Bordage (1898), Figdor (1911), Tournois (1914), have succeeded in changing the sex of various dioecious plants by making use of various methods, all of which consist essentially in a modification of the general nutrition. We also possess certain facts which indicate that the same thing is true as regards animals. The observations of Malaquin (1909) concerning the Monstrilliæ (Crustaceous parasites of Annelids) establish a very close relation between the number of embryos which develop in a single host and their sex: there is no female unless there is only a single embryo; the presence of several embryos or of equivalent conditions causes the production of males. According to Baltzer (1914), the embryos of the Bonnellia (a gephyrian worm) become males when placed in contact with an old female but become females on the contrary if they remain isolated. Finally, Patterson (1917) established the existence of individuals of both sexes in the same swarm of parasitic Hymnoptera. But since this swarm resulted from the segemtation of a single egg all of the individuals should have been of the same sex according to accepted theories. The production of a mixed swarm implies a secondary modification whose agent must necessarily have been some external factor, no matter what the cytological process which it occasioned.

Thus it will be seen that proofs abound and multiply as fast as biologists probe more deeply into the analysis of the conditions of the environment and succeed in making their observations exact. But the question arises as to whether we are able to state positively that a certain kind of nutrition determines the condition of sexuality or either one of the two sexes. The answer must be in the negative. While the results do depend upon external influences, they depend equally upon the organism itself; while "starved" cultures produce conjugation in the Infusoria, exhausted mediums suppress sexuality on the contrary, in the Mucorinæ; a moderate diet retains parthenogenesis in the Rotifera, while a more abundant supply of food appears to be useful in this respect in the case of the Clabocera. Hence we see that the details of the necessary conditions are different in each different case; the only thing that remains constant is the existence of a precise determinism at the basis of sexual differentiation.

Furthermore, this differentiation fully constitutes sexuality. There is no possible transitional state between the non-differentiated and the differentiated state; there are nothing but morphological intermediates which in no wise corresponds to more or less sharply defined degrees of sexuality. From the moment when two organisms acquire such a nature physiologic-

*Translated for SCIENTIFIC AMERICAN SUPPLEMENT from SCIENTIA (Bologna).

ally that they attract each other and then enter into complete or partial fusion sexuality exists integrally and all possible morphological complications have in general only a very limited degree of importance, which it is quite erroneous to believe fundamental or to consider as indicating "the evolution of the sex." According to all the evidence it is the physico-chemical differentiation which constitutes the sexuality. It must be acknowledged, certainly, that when the initial differentiation is once established various consequences follow therefrom; but it is an error to take these consequences for the point of departure. Morphologists in general believe that the sexuality attains a superior degree when the two individuals which unite are of unequal size instead of being externally similar. The possibility of calling the smaller one the male and the larger one the female would constitute a perceptible degree of progress. But the fact is that this morphological distinction is of no importance as a general thing. Establishing itself in the most diverse organisms the physiological differentiation must necessarily be effected in very various conditions, which may sometimes influence the external aspect and sometimes not. Furthermore, we may observe in the same species, as Collin has pointed out, a graduated series between the morphological similitude of the individuals which are conjugated and a marked lack of resemblance between them: nothing authorizes us, however, in considering the individual of a single generation and a single species as being more highly evolved in some cases than in others.

* * *

Another discussion has been waged among morphologists as to whether hermaphroditism is to be regarded as a primitive or as a secondary arrangement. The presence of the two sexes in the same individual sometimes gives the illusion of a greater simplicity than where there is a separation of the sexes upon distinct individuals. But as I remarked at the beginning since hermaphroditism implies the existence of differentiated sexual products, it necessarily implies the state of sexuality. Furthermore, if we pass in review the so-called "simple" organisms, we find diœcia in some of them and monœcit in others without being able to establish any connection between them. As a matter of fact, from the moment that sexual differentiation is established it concerns either distinct individuals which is generally the case in the Infusoria and various Fungi or else different parts of a single individual, which is the case in Algae or Fungi, in which two cells of the same thallus become united by means of a protoplasmic bridge. In one case or in the other the phenomenon is fundamentally the same. There is nothing to prevent the separation of the sexes (gonochorism) from being followed by hermaphroditism or vice versa. The question is of no general interest; the same fundamental determinism is applicable to both and each depends upon accessory circumstances which are difficult to define[1] the initial fact remains strictly the same.

II—THE CONSEQUENCES OF SEX.

This initial fact also enables us to understand all the peculiarities due to the sex condition. From the moment that there exists a physiological differentiation between individuals numerous chances exist that these individuals will not exactly resemble each other. Without being an absolutely general phenomenon sexual dimorphism is of exceedingly wide occurrence. In a very great number of animals the male can be distinguished from the female by one means or another, and the difference proceeds naturally from the difference of the metabolism.

Does this explain the determination of the sex? The question is complex. It is quite certain that in many cases (according to experiments with plants and observations by Malaquin and by Baltzer) external influences act upon an organism in process of development, directing its metabolism and consequently determining its sex. But in other cases the sex is determined from the moment of fecundation and appears to depend upon the presence or the absence of a particle of the substance of the nucleus (the sexual chromosome) in the spermatozoids. The latter exist, therefore, under two forms, one of which has one chromosome more than the other (or else the same number of chromosomes one of which is smaller); the female corresponds to the first and the male to the second. Here it might seem external circumstances are without effect and it might be believed that the metabolism depends upon the constitution of the nucleus. But if we carry the analysis further, we can readily prove that while the metabolism of the fertilized egg depends in some measure upon the nature of the fertilizing spermatozoid the latter, itself, certainly depends in its turn upon the conditions in which it is formed. The dimorphism of the spermatozoid proceeds, indeed, from the fact that at the moment of the formation of these sexual elements, one of the chromosomes instead of dividing, like all the others, into two similar portions, passes as a whole into one of the spermatozoids. It cannot be doubted that this mode of division depends upon the conditions in which the spermatogenesis is effected; hence we need only modify these conditions in order to modify at the same time the constitution of the spermatozoid. Furthermore, the facts of bisexual poly-embryology studied by Patterson, lend themselves to the support of this view;[2] they show in all cases that the spermatozoid does not carry with it an inevitable determination.

* * *

The question with which biologists have most occupied themselves is that of the utility of the sex condition, and likewise the utility of the separation of the sexes, as compared with their union in hermaphroditism. The opinions with regard to these questions are not very coherent it must be acknowledged. Darwin, at first believed that he had demonstrated that the sexuality, by rendering possible cross breeding between different individuals, increased the fertility and thus multiplied the chances of persistance of the species. Somewhat later Maupas expressed a similar idea in a different form, by speaking of "rejuvenation."

If sexuality were a necessary phenomenon, aside from contingencies, and if only cross-fertilization existed, the assertion would have had some foundation to support it, since it might be thought that a selective process had eliminated the organisms not fulfilling the required conditions. But this is not true. As my foregoing argument has shown there are a number of organisms where the suppression of the sexual process of reproduction does no harm; we know also that certain others reproduce themselves indefinitely in an a-sexual manner, and this without experimental intervention: among several ostracod and phyllopod Crustaceans, no males have ever been discovered, and parthenogenesis has been observed among the Cypriidæ continuously for more than six years. In the same way, certain Insects, such as the *Caravsius morosus* have continued to multiply in laboratories for many years without any previous coupling and without showing any sign of degeneration.

Doubtless there are many monœcious plants, of which Sirks has recently made a record (1917), self-fertilization is without efficacy in ordinary conditions and fructification is secured only by cross breeding; according to Castle and Morgan there is a Tunician which behaves in the same way. But here again the question of the medium intervenes. As a matter of fact, in the Pear, and in the *Abutilon* Darwin's self-fertilization is operative in some regions and inactive in others. Moreover, in a single species of Reseda there exist some "races" which are capable of self-fertilization and others which are not so. Finally, and on the contrary, self-fertilization is the rule, and almost an anatomical necessity, for a large number of plants—the pea, for example. Among various Fungi fertilization occurs between two consecutive cells, one the parent of the other, and Guillermond has witnessed in the Yeasts a conjugation effected between two sister cells which had hardly separated; it even happens among Bacteria that a sexual process is established between two incompletely separated parts of the same individual.

In all these cases there can be no serious question of rejuvenation, since the reunion of two masses of protoplasm which were united only a moment before evidently makes no change in its constitution.

These phenomena of automixia obviously govern the situation and impart to the condition of sex its true import. The effect of the interaction of the organism with its environment, the production of sex involves certain consequences, of which all that we can say is simply that they have not on the whole been of injury to the life and the persistence of the organisms. To say that they have exerted a favorable action is certainly going too far. Very often, on the contrary, the sexed state presents a very serious obstacle to reproduction, since it requires the meeting of two individuals who may be separated by a great space. And even when some advantage seems to accrue it is apt to be rather illusory. If it be true, as Darwin tried to prove, that fertility is increased by crossing, the increase is not so great that the process can be regarded as really useful.

Confronted by the difficulties inherent in the idea of a rejuvenation Jennings (1913) believed that in the special case of the Infusoria the conjugation is of benefit by occasioning a recombination of hereditary characters. But this point of view does not differ essentially from that of rejuvenation and is a mere question of phrasing. It is opposed by the same facts and they are equally available and in the same fashion.

* * *

Furthermore the facts of hermophroditism clearly indicate the vicious circle in which the theories revolve which seek above all to find the supposed "advantage" of anatomical arrangements and functions. Naturalists declare that hermaphroditism accompanies the fixed or parasitic life. According to all the evidence the reunion of the sexes on the same individual would form a valuable compensation for the impossibility these organisms encounter of changing place and meeting each other. This reasoning appears on the surface to be strictly logical. Unfortunately, however, it starts with faulty premises and is the result of a very superficial examination. When we penetrate further into details it is easy to detect the error involved. A very large number of animals exist which are hermaphroditic though free to move, the best known being the Earth Worms (*Lumbrics*), the terrestrial gastropod Molluscs and several of the marine ones, and various non-fixed Tunicians and Coelentera; on the other hand a very large number of fixed animals are unisexual, including the lamellibranch Molluscs, about half of the Bryozoa, most of the Sea Anemones and a good part of the Polyps.

In the second place, among the bisexual parasites, some of them belong to groups which also contain free representatives. This is true in the case of the Trematods, all parasites, but closely akin to the Turbellaria, which are all free. In this vast group only a single species is unisexed, and this very one is a parasite.

Finally hermaphroditism does not inevitably exclude the necessity of cross breeding—e. g., self-fertilization is impossible in the Gastropods and the Lumbrics; hence these animals pair. Still more striking is the fact that certain parasites, such as the bopyrean Crustaceans are successive hermaphrodites; the same individual never contains both male and female products at one and the same time, so that reproduction cannot take place without pairing.

We are bound to conclude from such facts that if hermaphroditism is non-effective it differs but slightly from gonochorism, while if it is effective it represents a useless complication, since agamia is a process far more simple in every respect. The fact of the matter is that gonochorism and hermaphroditism do not correspond to any anthropomorphic utilitarian reason whatever, but rather to divers conditions resulting from the interplay of the organism and the milieu which do not injure the persistence of the organism.

* * *

But even if the utility of sex to the species be clearly controverted, may it not nevertheless constitute an important factor in the evolution of organisms? An entire school, followers of Weismann has declared and proclaimed this to be the case. It is evident that the interaction of two cells adds to all the causes of variation which an organism may encounter in the course of its existence. Neither can it be denied that fecundation sometimes produces modifications of living substance which function in a different manner from the parent elements, and such a modification is frequently revealed by a morphological variation. But for this to take place it is requisite that the two elements united shall differ considerably from each other. If they differ but slightly, as generally happens when fecundation takes place between members of the same species, or between very closely related individuals, the chances of variation are reduced to a minimum.

However, it is not to variations of this sort that this school attaches importance. They have in view the combination of "factors," i. e. of entirely hypothetical particles which are supposed to represent in the living substance the morphological characters of the organisms and to be independent, autonomous, and interchangeable. Passing from one individual to another by way of conjugation they are supposed to form all sorts of combinations so as to produce new forms, and thus favor evolution. But these combinations in nowise represent variations, since they undergo no change in passing from parents to descendants.[3]

Furthermore evolution did not wait for the arrival of sex to begin and pursue its upward way and it con-

(*Continued on page 11*.)

[1] T. H. Morgan, who readily mistakes phrases for ideas, believes that hermaphroditism results from a "somatic segregation" without perceiving that he has merely replaced one word by another without shedding any new light on the subject. He also states that "the formation of the ovaries and the testicles takes place in the same manner as that of all the organs of the body," which again is nothing more than a verbal formula (*Heredity and Sex*), 1914, p. 167.

[2] Upon the subect of *The Determination of Sex*, see the excellent work of Amédée Bonnet, Lyons, Storck, 1914.

[3] Upon this subject see my articles: *Foundations of a Theory of Heredity*; and *Sketch of a Physiological Theory of Heredity* (Revue Philosophique, Feb. & March, 1918).

Kiln-Drying Specifications for Airplane Lumber

Inspection is Inadequate for Airplane Woods and Careful Studies Were Made to Secure Detail Specifications

By H. D. Tieman, M.E. M.F.*

BRASHNESS, internal stresses, and hidden checks produced by poor drying may be passed undiscovered in the most rigid inspection, since they cannot always be determined by direct examination of the material. The drying process itself is, therefore, of prime importance, not only for the saving of material through the avoidance of due waste from injuries in drying but even more so for the assurance that the material which passes inspection shall be free from subtle defect or possible weakness. For this reason it has become necessary to draw up very careful specifications for the drying operations themselves, and to place inspectors at the kilns to see that the operations are conducted in accordance with the specifications. The need for this was realized when the airplane program was undertaken at the beginning of the war, and the Forest Products Laboratory of the U. S. Forest Service, Madison, Wis., was looked to for the necessary information.

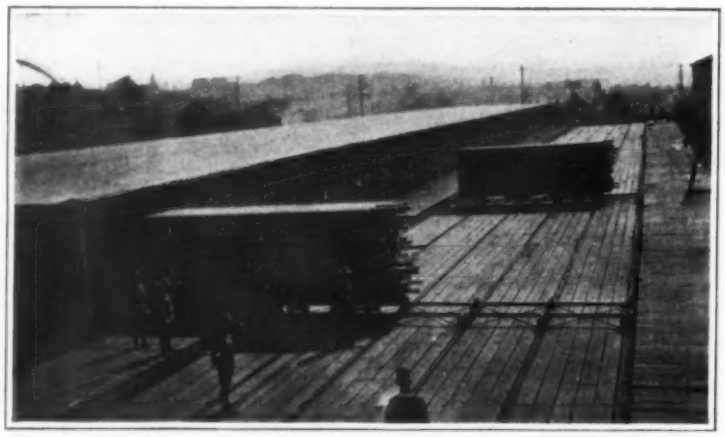


Fig. 1—General view of dry-kilns, U. S. Signal Corps, Vancouver, Wash. First loads of airplane wing beams being removed from the kilns

The Signal Corps specifications[1] were prepared on the basis of this previous knowledge of drying and of the mechanical properties of woods. The results of a few preliminary tests made in April and May, 1917, upon some airplane material of partly air-dried spruce and ash were also taken into account.

NECESSITY FOR MORE EXACT KNOWLEDGE AS TO STRENGTH.

It was evidently desirable, however, to establish definitely and beyond all question what effect would be produced upon the strength of the wood by methods of drying given in the specifications, and to obtain more exact knowledge about the limiting conditions for each species of wood as regards the severity of treatment beyond which it would be unsafe to go. This called for exhaustive drying and strength tests, which were at once undertaken at the Forest Products Laboratory. Shipment of logs of various species were received at the Laboratory. The logs were sawn, and materials selected therefrom were kiln-dried under different sets of conditions. Mechanical tests were then conducted to compare this material with matched green specimens, and also with matched specimens that had been set aside to air-dry under most favorable conditions. This requires the lapse of considerable time before the final analysis can be made, in order that the material may be properly air-dried. The first and most urgently needed part of this problem has already been worked out, demonstrating the safety of the drying conditions as recommended in the specifications, but the second part has not yet been completely solved, and the experiments are still under way.

VISUAL INSPECTION NOT SUFFICIENT FOR AIRPLANE WOODS.

For nearly all commercial uses, it is sufficient that wood be dried without any visible injury or any defect that can readily be detected by inspection. But to the manufacturers accustomed to handling wood for ordinary purposes, and more especially to the lumber dealers who are used to the commercial grading rules and methods of inspection, the selection of wood for airplanes is like learning a new business.

The chief invisible defects not covered by ordinary grading rules are brashness, spiral grain, casehardening (internal stresses), and minute checks produced in the drying that have closed up again and become invisible.

Methods of inspection, for the detection of these subtle defects are, as yet, by no means satisfactorily worked out. Moreover, inspectors are necessarily inexperienced in this line of work, as such examinations are comparatively new, and no specific tests are known for determining positively whether a particular piece is suitable or should be rejected. Much depends upon judgment founded on experience, and, as the latter has necessarily been lacking, errors have frequently been made.

ADVANCE ROT.

In this connection, the question of "advance rot" as affecting the toughness of the wood is of great importance. Even where there is apparently no evidence of the actual presence of fungus hyphæ, the enzymic action has been known to extend some distance into the otherwise sound wood, altering the chemical condition of the cell walls and causing the so-called "advance rot."

A test made within the elastic limit of the material will establish its strength up to the amount of stress imposed, but it does not indicate what will be the behavior of the piece if it is suddenly made to withstand a load considerably in excess of this amount. On the other hand, a test made on an adjacent piece of wood fails of its purpose, as the defect may be confined to the one specimen and not occur in the representative piece tested. This throws us back upon a visual examination based on the intimate experience of the inspector; but, at the present time, mechanical test within the elastic limit is probably preferable.

The test to maximum load of struts that fall in the long-column class is adequate to determine the load-carrying capacity of the strut, and the test may be made without any injury to the strut. Such tests however, cannot entirely take the place of visual inspection. Visual inspection is needed in this case to detect defects which, while not affecting the maximum load, would have a tendency to produce failure very early after the maximum load was passed.

SUITABLE DRYING CONDITIONS.

The accompanying curves give the temperatures and humidities suitable for kiln-drying airplane material without injury. The length of time shown is only intended as approximate, as it will vary greatly in different kilns.

In these curves the temperature is of the hottest portion of the pile of lumber. The relative humidity and the moisture percentage of portions of lumber subjected to these same conditions are also given. It is not intended that these curves should represent the continuous conditions at all times, but they represent the maximum temperatures and minimum humidities which should prevail for any considerable time, and a condition wihch should be approached as nearly as possible. Milder conditions are permissible, but not more severe. Steaming in saturated steam at the beginning of the drying with a temperature not more than 15° F. higher than the initial drying temperature, and combining 6 hours for every inch in thickness, is permissible and usually desirable inch in thickness, is permissible and usually desirable for green wood; for previously air-dried wood, 8 hours for every inch of thickness may be allowed, with a temperature not over 30° higher than the initial drying temperature. Near the end of the run, the material, if casehardened, should be steamed for not more than 3 hours, in saturated steam at a temperature 20° higher than the final drying temperature. After steaming the normal drying conditions should be resumed, and the excess moisture added by the steaming should be removed from the lumber. An average dryness of 8 per cent, with an individual variation of from 5 to 11 per cent, is ordinarily required.

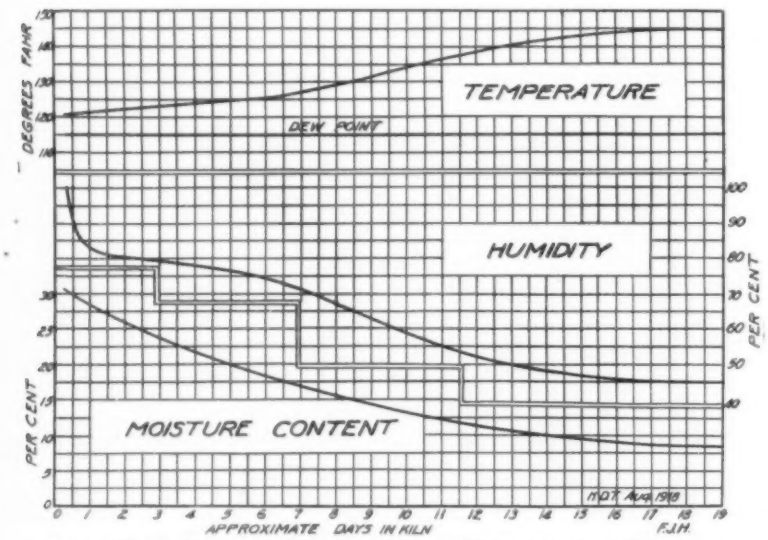


Fig. 2 Conditions suitable for kiln-drying 3-inch spruce plank. (Constant dew-point method of 115° F.)

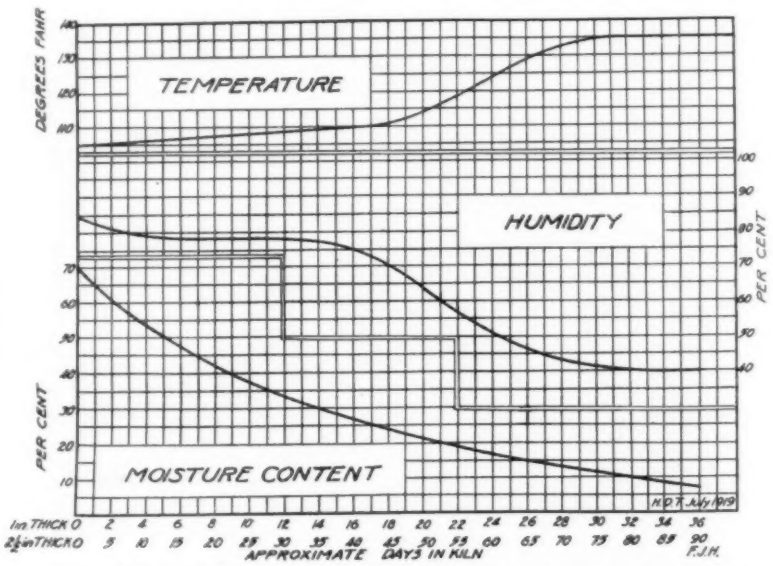


Fig. 3—Conditions suitable for drying oak, black walnut, mahogany or Douglas fir 1 or 1½-inch thickness.

*Forest Prod. Lab., U. S. Forest Service, Madison, Wis.

[1]Specification 20, 500-A for Kiln-Drying Airplane Stock, Air Service, U. S. War Department (SCI. AM. SUPPL., No. 2269.

Wind Resistance and Railway Speeds*

How the Model of the Engine Front Affects the Train Speed and Power Consumed

By C. F. Dendy Marshall, M. A.

In the case of a body travelling through a fluid at a high velocity, the resistance experienced depends on the shape to an extent that has only been realized of late years. In theory, at all events, a perfect "stream line" body should experience no resistance, except that due to skin friction.

It is obviously impossible to approximate at all to a stream line form in the case of a train, but that is no reason for going to the other extreme, and utterly ignoring the question of shape.

Little has been done to try and improve matters, except that about five and twenty years ago, on the South-Western Railway, Mr. Drummond made some of his smoke-box doors conical in shape, a plan followed on some continental railways, and that on the Paris, Lyons and Mediterranean, a wedge formation with the same object appears to have been aimed at. Neither of these efforts met with practical success, the theory of the air resistance to bodies moving through it being comparatively undeveloped, and the necessary experimental data lacking. The cone on the smoke-box door took the place of a flattened hemisphere of comparatively quiescent air which is pushed along in front of the ordinary door. So far as it may have encroached beyond that, it must have intensified the pressure on the outer part of the front. With regard to the French engine, merely substituting sloping surfaces for upright ones is an expedient that is of rather problematical value, and one which, under certain conditions of wind and speed, has the effect of increasing the side pressure on the rail.

Thanks to the work which has been done in connection with aeronautics, it is now possible to take the matter up and study it on a scientific basis, with a promise of substantial improvement.

The importance of the front wind pressure on the engine is not fully appreciated. The horse-power required to overcome it increases with the *cube*, not merely of the speed of the train, but with that of what is called the "created wind," which in the case of an express train may easily exceed 80 miles per hour.

It may now be taken as established that, for speeds within, and even far beyond, the range of railway speeds, the resistance of the air to a surface moving normally to itself is represented by the expression KAV^2, where A is the area exposed, V the speed, and K a constant. If A is measured in square feet, and V in miles per hour, $K = 0.0033$.

The constant 0.0033 applies to the total resistance, and includes the now well recognized suction on the back of a moving body. For plane surfaces normal to the wind M. Eiffel found in his famous experiments that the suction accounted for 1/3 of the total. The frontal pressure alone may, therefore, be taken as $0.0022AV^2$, and the horse-power required for every square foot of exposed surface is

$$\frac{0.0022V^3}{375} \text{ or roundly } \frac{6}{10^6}V^3.$$

The value of this expression is shown by the curve in Fig. 1. At 60 miles per hour it is approximately 1¼ horse-power, and at 80 miles per hourse 3 horse-power.

If we know the "all out" speed in a calm, say, 70 miles per hour, numerical limits can be assigned between which the speeds will lie for any ratio of train to wind speed. These limits are shown in Fig. 2.

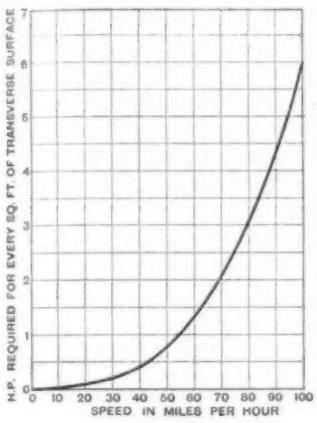


Fig. 1

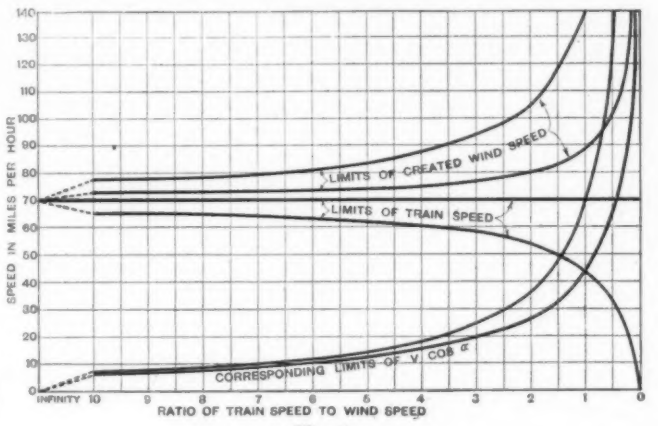

SPEED IN MILES PER HOUR
LIMITS OF CREATED WIND SPEED
LIMITS OF TRAIN SPEED
CORRESPONDING LIMITS OF V COS α
RATIO OF TRAIN SPEED TO WIND SPEED

Fig. 2

Here $V\cos a$ represents the resolved part in the direction of travel of a wind blowing with velocity V at an angle a to the rails.

It will be readily understood without entering into calculation that the speed of the created wind creeps up as the strength of the natural wind increases, and that 80 miles per hour is quite a moderate figure to take for it, while Fig. 1 shows how sharply the demand for power runs up with any increase of speed in that neighborhood.

We now know fairly well what is the best shape for a body which is to be driven through the air at speeds of the order under consideration. The front should be quite "bluff," a sharply conical or wedge-shaped form not being at all the ideal to be aimed at. What is required is to eliminate every square inch of transverse flat surface that can possibly be dispensed with, smoothing off projections, and putting in gentle curves parallel to the natural flow of the air.

It fortunately happens that the modern "extension" type of smoke-box lends itself beautifully to modification in this direction, without requiring to be made at all unsightly. Take a large smoke-box, 5ft.8in. diameter. The area is 25.23 square feet. With the very slight bulge usually adopted for the door, the front may be taken as equivalent, so far as the pressure is concerned, to a flat surface, more especially as the effect of the present bulge, if appreciable, is to increase the pressure on the flat annulus surrounding it. The horse-power absorbed for $V = 60$ is 32; for $V = 80$ it is 75.

It is a simple matter to reduce these figures to an extent that is hardly credible. If the ring at the front end of the box is made only just large enough to carry the door, as shown in Fig. 3, say 4 ft. 8 in. diameter, instead of 5 ft. 8 in., the front surface is reduced by 8.12 square feet. This is all to the good, because there will be no pressure whatever on the coned part of the covering plate. The result is a clear saving of 10½ horse-power, when $V = 60$, and no less than 24 when $V = 80$. There appears to be no objection to this modification; the stationary portions of the hinges would have to be fixed on the covering plate, being shaped to fit it. The iron for the head lamp and the transverse part of the hand rail should be carried on the door, as is frequently done at present. But we can go farther than this. By forming the door with a radius of something under 3 ft., instead of the usual one, which is frequently as much as 18 ft., we can produce a front contour which is quite excellent from an aerodynamical point of view. M. Eiffel found that the resistance of a cylinder with hemispherical ends was only 1/5 that of the same cylinder with flat ends. It is reasonable, therefore, to expect this smoke-box to effect a saving of the order of 25 horse-power, when the created wind speed is 60 miles per hour, and 60 h.p. when it is 80. The pressure against the surface immediately below the extension will now be greater, but this effect will probably not amount to very much. A smoke-box of this kind is shown in Fig. 4.

There is another point about this door. The edges form part of a cone of 120 degrees and shut into a ring forming a portion of a 60-degree cone, the result being that it is first drawn up tight by the screw, and then a further turn or so will flatten it slightly, tending to spread it at the edge, and effectually sealing the joint. At the same time, when the pressure is taken off, the tendency to stick would be easily overcome by pulling it, owing to the ring being conical, and to the fact that if it did seize, a sharp pull outwards would tend to contract it. The hinges should be of the "strap" type, as a solid hinge would cause a local stiffening of the edge, and the attachments for the liner should be kept away from the edge, in order to allow it to "give" when screwed up.

It is true that doors with a fairly pronounced bulge are sometimes seen on the Continent, but any gain due thereto is almost entirely neutralized so long as the flat ring surrounding them is retained, as the latter stems the flow of air off the door, and would be subject to considerably increased pressure on that account, besides producing eddies all round the edge.

It has been shown that the shape of the locomotive will repay careful study, and that some modifications may be so profitable as not only to be worth making in the case of new engines, but possibly even sufficiently valuable to be introduced into existing ones as they come into the shops for heavy repairs. But much more may be done in the design of new ones. Everything on the outside of the engine must be considered from this point of view. Experience with

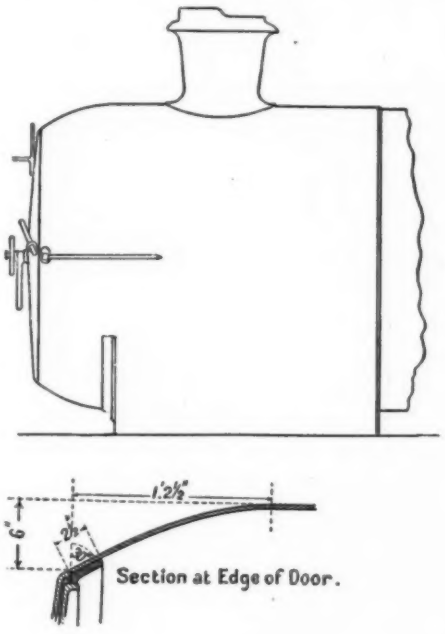


Fig. 3

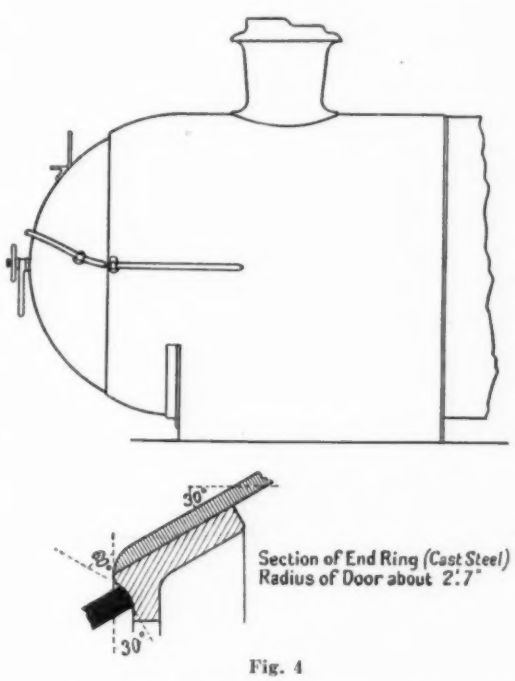


Fig. 4

*Reproduced from *The Engineer* (London).

aeroplanes shows that nothing in the way of reducing surface, and "fairing" excrescences, is too trivial to be worth while. Merely stream-lining the wires in one case produced an increase of 10 miles per hour in speed.

We can begin at the buffer beam. This should be made just only wide enough to carry the buffers, and the footplate and framing, or angle iron, as the case may be, sloped outwards, arriving at the desired width about 2 ft. 6 in. back. This alone is worth anything up to 8 horse-power.

The front covers of outside cylinders should be shaped like the smoke-box door in miniature, which would also have the effect of reducing the radiation due to the air impinging upon them. The dome is not a bad shape as it stands, but it is in a very exposed situation, and it is probably worth a few horse-power to make it die away to a point on the top of the boiler between two and three diameters behind the present center. Splashers should be of the "Worsdell" pattern. Generally speaking, where the cross area of the engine has to be enlarged, it should, if possible, be maintained, all pockets being avoided, as they have a very bad effect, especially in a side wind. With regard to the cab, the writer is not at the moment in a position to make any very definite suggestions as to the best shape. It is a difficult problem; but one thing is certain, there should not be any suspicion of "eaves" in front, since the slightest projection here would catch the wind very badly. Mr. O'Connor's engines on the Caledonian might be remembered in this connection, as they had a convex curve at the top corner. This almost seems to call for a flat top where the curve merges into the horizontal, but the roof could then be bulged like those on the Stroudley engines. If the front is straight across the engine, the side plates should be swept up from the top of the splashers with as large a radius as possible, the center of the arc being level with the bottom of the front windows.

It is worthy of note that the only feature of the Paris, Lyons and Mediterranean engines already referred to which has survived is the wedge-shaped front to the cab, a feature which has been copied on many continental railways, not merely with the object of diminishing air resistance, but also on account of convenience. The large diagonal windows are a distinct advantage, and these cabs are also good from the point of view of ventilation.

The tender should be made the same shape and height as a carriage, with curved sheet iron doors to cover the coal. With the present arrangements, the rough surface of the latter causes much resistance, and if the tender be low, the upper part of the front carriage has to start all over again, so to speak, with the air. The carriages should, of course, all be of the same cross section, and as smooth as possible outside. The present sunk windows and panels present a very considerable area to a wind blowing nearly ahead, as will be realized if it is all added up. Probably the windows must be slightly sunk, for constructural reasons, but the usual panels are unnecessary. Again, it is a case of every trifle tells.

As has been often suggested, it would be advantageous to close up all the gaps between the bodies of the coaches with flexible connections, irrespective of whether there is a gangway or not. If this be too much to ask, perhaps the principle of close coupling could be extended to main line trains, partially, at all events. By partially, it is meant that the trains might consist of a nucleus of close coupled vehicles, with such extra ones as might be necessary tacked on at the ends. The fact that the carriages are closer together on some lines than on others shows that the intermediate spaces are not always as small as they might be. Another slight improvement, by no means to be despised, might be made by "fairing" the accumulator boxes, the front surfaces of which on a long electrically-lighted train mount up to a good deal. The same applies to brake reservoirs.

We have now arrived at the back of the train. Here much might, but it is feared nothing can, be done. In a "stream-line" body, the tail is of far more importance than the head. But practical considerations preclude the idea of running a long bogie car tapering away to a point at the back of an express train, although it would probably be well worth the cost of building them. Evidently the place to attack is the front, and it is hoped that this article will have the effect of drawing attention to the amount of power that is being unnecessarily thrown away, a subject which has been present to the mind of the writer for years, and in which he tried to arouse interest fourteen years ago, but without success.

Since writing the above the writer's attention has been drawn to the "Report of the Electric Railway Test Commission," New York, 1906. This report contains most striking evidence of the importance of the question of shape. On page 570 a table is given showing the relative power required to force different shaped front vestibules through the air. At speeds between 40 and 80 miles per hour parabolic shapes take only about 50 per cent. of that required by the standard (American) vestibule, while a flat front takes 180 per cent. The statement is also made (page 572) that with the power at hand the test car when fitted with a flat front could not be driven over 50 miles an hour, whereas with a "parabolic wedge front" 75 was easily attained.

A few pages farther on the report contains the following remarks as to the bearing of the results on steam trains. "From the standpoint of wind resistance nothing worse than the standard type of locomotive can be imagined, with its multitude of irregular projections. The experience of engineers and firemen in putting their heads out of cab windows is such as to demonstrate the great resistance met by such obstacles. The resistance offered to all high-speed steam trains by the air would be materially diminished if the locomotive were housed in a shell, and if pains were taken to remove all unnecessary projections from the coaches, and further, if the outline of the tender were made to conform to the general cross-sectional shape of the train."

The recommendations of the Electric Railway Commissions agree closely with the opinions of the writer, which have been formed quite independently, and the carrying into effect of which involves no increase of expense or sacrifice of efficiency. Nor are there any additional surfaces to be introduced which might prove detrimental under some conditions of wind.

Brown Patches in Lawns and Pastures*

BROWN patches in fine turf have long been known, and, as they commonly occur in midsummer, have usually been ascribed to "sun scald." Observation of the spots as they occurred in 1914 near Philadelphia furnished strong evidence that the cause was an organism, but the pathologists who studied specimens failed to disclose the casual agent. The abundant occurrence of the trouble in the vicinity of Washington in 1916 and since gave opportunity for study. The brown spots usually appear in summer with the advent of hot moist weather and are most conveniently studied on well-kept turf. The spots are at first small, but increase rapidly in a concentric fashion, reaching a definite size varying from a few inches to 2 or 3 feet in diameter, and then cease spreading. In the early morning a fine white mycelium may be observed over the discolored turf. Cultures from this as well as from sclerotia on the stems proved the fungus to be the well-known *Rhizoctonia solani*. From artificial culture it was easy to induce the formation of brown patches in grass turf under favorable weather conditions.

The fungus is known to attack an enormous list of herbaceous plants, but strangely enough has never been reported as attacking any grass, although there is one record of the occurrence of the mature form of the fungus (*Corticum vagum*) on maize.

Rhizoctonia is, however, very common in lawns and pastures and has been observed by the authors in many places from Minnesota to Maine and southward to the Ohio and Potomac Rivers. Among the plants attacked are redtop, red fescue, Rhode Island bent, carpet bent, velvet bent, Kentucky bluegrass, rough-stalked meadow grass, as well as many lawn weeds. Crab-grass and Bermuda grass seem perfectly immune, as is also white clover.

Most of the grasses slowly recover in the brown patches with the advent of cool weather in fall, but some are completely killed. Certain strains of carpet bent and velvet bent grown in pure cultures near Washington are especially injured by the disease, but others are completely immune. Spraying at intervals with Bordeaux mixture helps protect the grass turf, but such applications need to be frequent.

Electric Underground Tide

MAKING use of the underground iron water and gas pipes supplying the St. Louis Observatory, Jersey, M. Dechevrens finds regular variations in the current indicated, with semi-diurnal maxima and minima, the period being lunar (24 hours 50 minutes covering two maxima and minima on an average). The maximum is associated with low tide. The annual minimum takes place two hours before the highest spring tide. Other features of the variation of ocean tides are also reproduced. The author concludes that similar effects should be found at all coastal stations.—*Science Abstracts.*

*Abstract by C. V. Piper in *Jour. Wash. Acad. Sci.*

The Credibility of Long-continued Experiments

AT the Rothamsted Experimental Station certain experiments are continued for a long series of years in order to amass sufficient data to allow of proper statistical treatment. Some of the experiments have been carried on since 1843, others since 1852, 1856, 1860, etc. A characteristic feature of the work is the length of time for which particular observers are responsible for their records, some being in charge of the same work for twenty, thirty, or forty years. The fundamental weakness in such long-continued experiments is one inherent in human nature itself: errors once introduced are apt to persist, and to cause much harm unless they are soon detected.

In many of the experiments it is not possible to institute any very satisfactory check on the results. In some cases, however, this can be done. The measurements taken at the rain and drain gauges afford an instance, and the agreement is so close as to deserve record.

In 1870 three drainage gauges and one rain gauge were set up at Rothamsted, each 1/1000 acre in area. The rain gauge is simply a very large funnel embedded in the soil; the drain gauges are also large funnels, but filled with soil to depths of 20, 40 and 60 in. respectively. In constructing them, however, the soil was not disturbed, but was left in its natural position, while the framework of the gauge, by an ingenious arrangement, was built round it. From 1870 to the present day readings have been taken of the amounts of water percolating through the drain gauges; this amount being some 40 to 60 per cent. of the water collecting in the rain-gauge. Samples of the water from each gauge are then sent to the laboratory, where the chlorine and nitric and ammoniacal nitrogen are determined.

This work went on without intermission from 1888 until 1916, when it was suspended owing to the sudden death of Dr. N. H. J. Miller, who had been in charge the whole of the time.

The results have now been calculated out and added up.

It is well established that soil neither absorbs nor gives up chlorine to water cantaining sodium chloride in solution, therefore the amounts of chlorine found in the drain gauges ought to be equal to that in the rain gauge if the numerous separate records were accurate. Over a short period there is always liable to be a difference, because some of the chlorine may not yet have had time to percolate, but over a long period this is eliminated. The actual results obtained at Rothamsted are:—

Chlorine in pounds per acre.

Average per annum for 4 years	From drain gages 20 in.	40 in.	60 in.	From rain gage
1892-96	14.15	15.19	14.24	14.35
1896-1900	16.26	17.61	16.07	17.90
1900-04	17.07	18.65	17.40	17.23
1904-08	16.23	16.18	16.00	16.75
1908-12	19.57	18.86	20.07	18.48
1912-16	19.02	18.95	19.58	19.14
Total amounts for 28 years				
1888-1916. . .	460.56	474.76	467.20	466.00

The number of measurements involved is very large; there are some 18,000 readings at the gages and a large number of titrations in the laboratory. The gage-reading has to be multiplied by its titration value, and the resulting figures are then added up. Considering the multiplicity of the data, the agreement in the results is remarkable; the widest divergence over twenty-eight years is only 2 per cent.

This close agreement is the result of careful daily work, and not of accident. There is no correspondence in the laboratory between the rain and the drainage samples; this is prevented by the carry-over of water and of chlorine in the drain-gages from day to day, and even month to month. Nor is there any possibility of straining readings to compel agreement; the figures were not regularly added up during the course of the work, but only at rare intervals.

The result shows how accurately continuous observations can be made provided care is taken. The readings at the gages have throughout been taken by Mr. E. Grey, who without fail and in all weathers has stuck to the work. The titrations were made by the late Dr. Miller, who would have felt great pride in the final result had he lived to see it. Fortunately, Mr. Grey is still in charge of the gages.—E. J. RUSSELL, in *Nature* (London).

Progress In Naval Aircraft—II*

Contributions to Naval Aircraft Design and Construction by the United States, Culminating in the "NC-4" Type

By Commander J. C. Hunsaker, Bureau of Construction and Repair, U. S. N.

[Concluded from Scientific American Supplement for August 2, 1919, No. 2274, P. 76]

Extensive tests have been made by the Bureau on the use of so-called fireproof dopes which consist usually of cellulose nitrate in which there have been distributed fireproofing ingredients such as di-ammonium phosphate, calcium, magnesium and zinc chlorides and also tricresyl phosphate in various combinations. Good results were obtained with di-ammonium phosphate.

New types of dope have appeared in recent years under the name of pigmented dopes, first used by the British. These consist usually of highly plasticized nitrate dope in which pigments and softening materials are distributed and are used in place of varnish. The wearing value and fire-resisting properties, however, are not as high as the naval gray enamel now in use by us.

Considerable work has been done by representatives of the Bureau in factory control of conditions at contractors' plants. This work covered the heating arrangements, removal of evaporated solvents, control of humidity conditions, design of fabric covering rooms, methods of dope application and factory control in operation, studies of ventilation and hygiene. The latter is a matter of some importance as cases of so-called dope poisoning have in some instances been observed, generally in the form of eruptions on the arms of the workmen or the development of greatly swollen hands. By the elimination of all highly poisonous dope solvents such as tetra-chlora-ethane and the installation of suitable ventilation systems much of this trouble has been obviated. Through the development of emollients the hands and skin of the workmen have been protected from troublesome effects.

GLUE FOR LAMINATED CONSTRUCTION.

The very extensive use of laminated construction for wooden parts of the NC and other Naval seaplanes is dependent upon the establishment of a correct glue practice. In the NC a good deal of hide glue had to be used because, while it was realized that such glue is not waterproof unless protected by varnish, developments in the use of casein and other waterproof glues had not proceeded far enough to render their use safe and dependable. Since the NC's were started, considerable progress has been made, and the present practice is to use waterproof casein glue throughout.

The British and German aircraft builders have used a type of casein glue composed usually of casein, slaked lime, caustic soda, sodium fluoride and paraffin oil, the three latter ingredients being used in small percentage. Contemporaneously American aircraft plants have been experimenting with types of casein glue for plywood construction produced in this country. The Bureau gave encouragement to experiments along this line and took up with the Forests Products Laboratory and the manufacturers the subject of the utilization of casein glue for strength parts of airplane construction. Through some intensive work, these glues were soon developed to such an extent that three were placed on the market by individual manufacturers in a form ready for use. These products were all thoroughly tested by the Forest Products Laboratory and found to give results which indicated their superiority over hide glue. The art of employing these glues in aircraft construction was developed with great rapidity. One of the prime requisites was the use of a power mixer for the thorough incorporation of the glue with the aqueous medium. The uniformly high strength of joints made with this glue soon indicated the value of using it almost exclusively in place of hide glue and instructions along this line were sent to all naval contractors together with information in regard to using this new type of cold glue. At the same time through arrangements made with the Forest Products Laboratory, men were trained and sent to the various plants to install the process and put it on a working basis.

At first some difficulty was had with laminated constructon where many laminations required a large quantity of glue and necessarily a large quantity of water. This water would pass into the wood and retard the hardening of the glue. Later on it was found that when these pieces were dried in a warm room or in a dry kiln in the same manner as wood having too high a moisture content, the excess water would evaporate and an excellent joint resulted.

Specifications were issued for plywood constructed with blood albumen glue, this type of plywood being extensively used for hull sides and tops. It was found that panels made with blood albumen glue gave much greater strength if tested immediately after long-time soaking than panels made with casein glue. For this reason the blood albumen glue is preferred for the construction of pontoons and hulls which are exposed directly to the action of salt water. The tops of some of the NC hulls are covered with blood albumen veneer and others with the usual two-ply spruce planking riveted over fabric set in marine glue. The latter practice is somewhat heavier and more expensive but has greater life in service due to local stiffness, elasticity and ample fastening.

The power plant arrangement was originally designed to employ three Liberty engines mounted between the wings in a symmetrical manner and driving three tractor propellers. The radiators were mounted in front of the engines in the slip-stream of the propellers so that a good current of air would blow through the radiator when running at a low speed on the surface of the water. The slip-stream was also used to drive the small windmills which pump gasoline from the main tanks in the hull to the gravity tank in the upper wing. In a similar manner, a small windmill-driven generator in the slip-stream furnishes current for the radio and for charging the storage battery for the electric self-starters.

A feature that is new in this boat is the use of welded aluminum tanks for gasoline. There are nine 200-gal. tanks made of sheet aluminum with welded seams. Each tank weighs but 70 lb., or 0.35 lb. per gal. of contents, about one-half the weight of the usual sheet steel or copper tank.

HOW THE NC BOATS WERE BUILT.

The plant of the Curtiss Engineering Corporation at Garden City, N. Y., was of insufficient size for the building of flying boats of the dimensions of the NC-1. It was, accordingly, necessary for the Navy Department to authorize the building, at its own expense, of a building attached to this plant of sufficient size for the complete assembly of two of these flying boats at one time. In addition, the ordinary facilities of the Curtiss company were such that it was certain that the attempt of that organization to carry out in complete detail the entire construction of these flying boats would be productive of most serious delays in completion. It was decided to build them on the assembly basis; that is to say, the various elements would be built by different plants turning out a product of a somewhat similar nature, or one requiring workmen of similar qualifications to those ordinarily employed for work of the nature of that in contemplation.[1] These different elements would then be shipped to Garden City to be assembled there into the completed flying boats. As a result of this decision, different parts were built at the following places:

Boat hulls—Garden City, N. Y.; Boston, Mass.
Tail booms—Boston, Mass.
Gasoline tanks—Pittsburgh, Pa.
Wings, control surfaces and struts—New York City.
Nacelles, major details, gasoline system and all wiring—Garden City, N. Y.
Metal fittings—Newark, N. J.; New York City.
Wing tip floats—Albany, N. Y.; Philadelphia, Pa.
Liberty engines—Detroit, Mich.

There was also not available at any operating station hangars of sufficient size for housing these flying boats. Construction was arranged for by the Navy Department at the Rockaway Beach Naval Air Station of a building of sufficient size for housing two of these boats. Due to their very large size, special handling arrangements of the marine railway type for getting them into and out of the water were necessary and were provided. Rockaway Beach was chosen for the location of the hangar and handling arrangements on account of its nearness to the corporation plant and of its excellent location for carrying out the flying tests which would be necessary.

The use of a marine railway for getting the boats in and out of the water is new for aircraft and has been found to permit the handling of these large and heavy boats with fewer men and with less risks of damage and loss of time than the conventional handling truck on rollers that is man-handled down an inclined concrete runway leading into the water. The boat in its hangar rests on cradles fitting the bottom and provided with four caster wheels. On this truck the boat is pulled out of the hangar to the marine railway by an ordinary agricultural tractor. The entire load including the truck is then shoved on the car of the marine railway and secured to it. The marine railway car has flanged wheels running on rails extending out into deep water. It is lowered away until the boat is waterborne and floats off the car. The marine railway car is then submerged with the handling truck and cradle secured to it ready to receive the boat on its return. Simple and positive means are provided for centering the boat when it is again floated in place over the cradles, and when it is secured in place the tractor runs it out. The whole operations takes only a handful of men and a few minutes' time.

The first of the flying boats was completed and flown Oct. 4, 1918, or approximately 1 year from the commencement of the design. The trials were a source of great satisfaction as it was soon demonstrated that the control and balance in the air were very satisfactory and in accordance with the prediction of the wind-tunnel tests, and that the performance on the water was all that could be desired and entirely justified the confidence placed in the model tests in the towing basin. No structural weakness developed and the speed came out as predicted. *In short, this flying boat* designed from theoretical and model experimental data, combined with the practical experience of a half dozen or more people, *performed in every way so close to its designed characteristics as to justify completely the methods of the naval architect as here applied in the design of a flying machine.*[1]

CHANGES MADE AFTER COMPLETION.

As flying tests on the first boat were continued, many changes were tried to improve the original design and, as these were found advantageous, were incorporated on this and on the other three boats building. The Bureau of Steam Engineering, at this stage, was able to improve the performance of the boat materially by the application of new propellers designed in that Bureau. The NC-1 was originally fitted with standard Navy low-compression Liberty Engines, which were found to be entirely satisfactory, but during the period that the NC-1 was being tested with these engines the Bureau of Steam Engineering, in its experimental laboratory at the Washington Navy Yard, perfected carbureter adjustments on the high-compression Liberty Engine which materially improved its economy. Since the high-compression engine gave greater power than the low-compression type, these engines replaced the original installation on the NC-1. With the new propellers and engines, the boat got out of the water and flew easily with a total weight of 24,700 lb. The designed load was 22,000 lb. Besides providing propellers and engines for the boat, the Bureau of Steam Engineering supplied a remarkably efficient electric self-starter to each engine. This type of self-starter, the Bijur, weighed only 35 lb., and by this improvement it was possible for the pilot to start any engine without leaving his seat. It is believed that this constitutes the first application of an electric self-starter to the Liberty Engine.

The month of November, 1918, was spent in thoroughly trying out the NC-1. Among other flights a round trip from Rockaway, N. Y., to Washington, via the entrance to the Chesapeake Bay was made with nine people on board. On Nov. 25 the NC-1 broke the world's record for passenger carrying, having on board in the air fifty-one persons. One of these was a stowaway, who had concealed himself in the interior of the hull for over 1 hour prior to the start of the flight and is probably the first man deliberately to stow himself away on an airplane to make a voyage. Of these flights Naval Constructor Richardson was in charge and was one of the pilots.

After making various minor improvements, it was concluded that the maximum which could be obtained from three Liberty Engines had been reached and no further improvements in performance could be expected until geared Liberty Engines became available. These were still in an experimental stage. It was apparent, however, that the flying part of the craft could sustain a greater load if more power were avail-

*Reprinted from *Jour. Soc. Automotive Engineers.*

[1] Italics are ours.—Editor.

able, and it was accordingly decided to add a fourth engine making a total of four Liberty Engines. The second boat completed designated as NC-2 was, therefore, fitted with four Liberty Engines arranged as two pairs of tandems and on its trials in March, 1919, successfully flew with a total weight of 28,000 lb. The addition of the fourth engine, which increased the dead weight of the boat by about 1,500 lb., permitted about 3,300 lb. of extra weight to be carried, or a net gain of 1,800 lb.

The NC-3 and NC-4 were completed in April, 1919, and were likewise fitted with four high-compression Liberty Engines but with a somewhat different arrangement. In these two boats two engines were arranged on the center line as a tandem pair with the other two engines mounted on the wings as tractors, as were the wing engines on the NC-1. In these boats a further change was made by omitting the center nacelle and placing the pilots in a cockpit in the hull. This arrangement of engines is novel and has the advantage of concentrating weights near the center of the boat so that it can be maneuvered more easily in the air.

Due to injury to two outer wing sections while at anchor in a gale late in March, the NC-1 was temporarily put out of commission. After the completion of weight lifting trials on the NC-2, the outer wing sections of that boat were transferred to the NC-1 as no spare wings were available. Except for this regrettable injury, all four of these boats would have been able to leave Rockaway Beach together for the transatlantic flight.

SPECIAL EQUIPMENT FOR TRANSATLANTIC FLIGHT.

The equipment of the boats for the transatlantic flight differs somewhat from the installation designed for antisubmarine patrol work. Bombs and bomb racks, bomb sights and release gear were omitted. The machine gun and gunner's position in an egg on the top plane were taken off as well as the gun installation in the bow and stern of the hull. The radio consisted of apparatus for sending both in the air and on the water besides the radio telephone and direction-finding outfit.

The powerplant equipment, consisted of the usual thermometers, pressure gages, tachometers, gasoline gages, etc., and for four engines amounted to a very complicated installation to be brought into the boat. Each engine has independent throttle controls and self-starter all brought together at the pilot's seat so that he has complete control of any and all engines at all times.

The equipment for navigating consisted of a bubble sextant, compass and a drift calculator which was improvised from the ground speed bar of Col. Crocco's ground speed indicator as used on Italian airships. This instrument was made up by the Naval Gun Factory from data supplied by Col. Crocco. Special slide rules and tables were prepared to shorten navigational calculations.

With boats as large as the NC's, the pilots no longer control the machine by the feel of it but must be provided with instruments to indicate at any instant just what the altitude is. The inertia is so great that the pilot cannot wait until a disturbance from normal flying condition becomes pronounced. What he wants is advance information so that he can check a tendency before it develops.

The most important instrument is the air speed indicator, as he must know whether he has flying speed and also whether he is flying at economical speed. During the war, various types of air speed meters were tried. Most consisted of the usual pitot tube connected with a sensitive pressure gage. For ordinary speeds, especially the low speeds, when leaving the water or landing, the pitot tube gives a very low pressure to be measured. Consequently, an exceedingly delicate pressure gage is needed. Our experience with such gages was not very satisfactory. No reliable and useful speed indicator was available until the Zahm type of venturi nozzle was developed in the Bureau. This merely replaces the pitot tube by a venturi tube. The latter for a given air speed gives several times the pressure of a pitot tube and requires only a cheap and rugged pressure gage. It had been found that flying through rain and spray water gets into leads and makes the speed readings false. In Dr. Zahm's instrument provision is made to keep it spray-proof.

Beside his air speed the pilot wishes to know the inclination or trim of the hull. For this a lateral and longitudinal inclinometer is provided. These are of the usual type, consisting of a bent glass tube filled with colored liquid. The only improvement added by us was the use of fluorescence in the liquid and the addition of a small electric light inside the instrument in such a manner as to be invisible to the pilot yet to cause the liquid to glow with a pale green light. For night flying the pilot should not have a bright light in his eyes.

To give warning of the start of a turn, the compass is not sufficiently sensitive and several forms of turn indicator have been used. A British type which is useful consists of two pilot tubes, one mounted on each wing tip, connected differentially with a pressure gage which registers the difference between the pressures generated by the two pilots. The NC's for the transatlantic flight were equipped with a Sperry gyroscope which tumbles at the start of a turn and gives early warning.

The boat has interior telephones for communication as well as speaking tubes. The latter are rather difficult to use when all four engines are going on account of the noise, but a special sound-proof helmet was designed which effectively cuts out external noises. The feature of this helmet is the use of a pad of sponge rubber to deaden external noises surrounding a metallic ear trumpet to magnify the sounds transmitted through the speaking tube. It has been found practicable to converse through a ¼-in. internal-diameter tube with the engines running.

Other equipment consists of sea-anchor, emergency rations and thermos flasks, special clothing, fire extinguishers, running lights, signal lamp and interior lighting arrangements.

A hand operated pump is provided to drain the bilges of water and a careful arrangement of ventilators flushes out any gasoline fumes which may accumulate in the hull.

A small supply of spare parts and tools for emergency repairs in flight is carried and proved its usefulness on the NC-4 enroute from Halifax to Trepassey Bay. Her engineer, Moore, noted that the gravity tank was leaking gasoline around some rivet heads after the flight had been under way for some time. This tank is located in the upper wing, immediately over the central pair of engines. He left his position in the stern of the boat, crawled along the top side and under the guard of the rear propeller and climbed up on top of the center engines and while going through the air at 80 miles per hr. stopped the tank leaks. To permit such a passage a sheet aluminum tunnel had been installed on top of the boat under the after propeller which prevents a man's clothes being drawn into the blades.

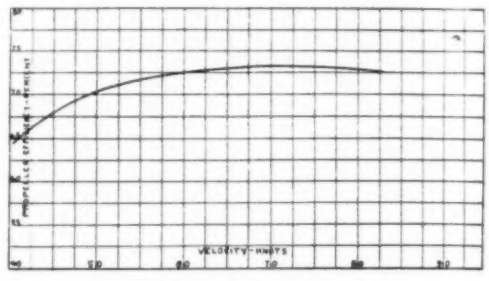
HORSEPOWER REQUIRED AND VELOCITY CURVE
Curves are calculated and the three points (x) are taken from actual test data on NC-2 trials at 28,000-lb. load

CALCULATIONS OF PERFORMANCE.

In designing the NC, it was at once clear that the cost would necessarily be very high for the first units not only on account of their unprecedented size but because of the great amount of experimental work necessary. Naturally, if the boats were a failure in performance the funds spent could hardly be justified. Very careful calculations of the relations between speed, power, resistance and endurance were made. I am very happy to say the performance actually realized on trials checked the calculations very closely. In fact, the precision of the measurements of speed, power and fuel consumption on the trials was such that we do not know whether the calculated or the measured values are nearer the truth.

The performance was calculated from a determination of the total drag of the machine at various angles of incidence and speeds, corresponding to different gross loads. In arriving at values of the drag for the various speeds, the angle of incidence of the wings was the determining factor. This angle of incidence was determined by the different gross loads which would obtain as the weight dropped off as fuel was consumed.

From these drag calculations curves were drawn of horsepower required plotted against velocity. The curves for various gross loads of the machine are given. Since for the transatlantic flight it was intended to fly these machines at their economical velocities to obtain the maximum possible cruising range, special propellers to give maximum efficiency over this speed range were constructed. The curve of propeller efficiency is reproduced in which allowance for the reduction in efficiency of the center pusher operating in the slip-stream of the center tractor has been made.



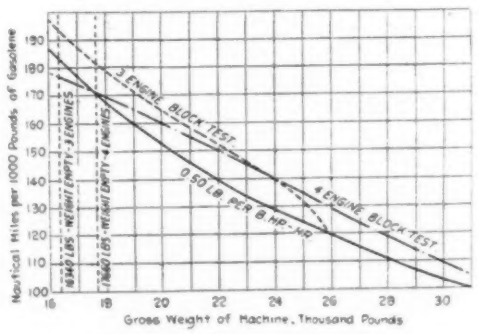
CURVE OF PROPELLER EFFICIENCY

The percentages in the following table give the distribution of this drag at a 5-deg. angle of incidence of wings and a velocity of 70 knots:

	Per cent
Hull, cockpits and appendages	4
Wing tip floats	3
Powerplants and radiators and installation	20
Tail booms and braces	1
Wing struts	3
Rudder and fin	1
All wiring	12
Stabilizer and elevators	3
Total parasite	47
Wings	53
Total drag	100

The economical cruising velocities in still air are those velocities which correspond to the maximum ration of the gross load to the total drag of the machine, assuming that the propellers will give their maximum efficiency and the engines will be so operated as to give their minimum fuel consumption per brake horsepower delivered at the velocities corresponding to this angle as the gross load decreases due to fuel consumed.

The brake horsepower used in computing the cruising range curves was determined by dividing the horsepower required at the economical velocities for the various gross loads by the propeller efficiencies at these velocities. The area under the curve between an abscissa which represents the gross load less gasoline and the gross load abscissa gives the maximum cruising range in nautical miles in still air. The cruising range is limited by the maximum load which can be sustained in the air. Assuming that the fuel consumption of the engines in flight will vary as the consumption on the block test in the laboratory, when the maximum gross load at which the machine will get into the air in sustained flight is determined for three and for four engines, the maximum cruising range can be determined for either installation. The area under the three-engine curve between the 16,340 and 17,670 lb. ordinats represents the increase in range due the weight saved on the fourth engine installation and the weight of oil to be consumed by it,


Nautical Miles per 1000 Pounds of Gasoline
3 ENGINE BLOCK TEST
0.50 LB. PER B.HP.-HR.
4 ENGINE BLOCK TEST
16340 LBS. - WEIGHT EMPTY - 3 ENGINES
17660 LBS. - WEIGHT EMPTY - 4 ENGINES
Gross Weight of Machine, Thousand Pounds

CURVE SHOWING MAXIMUM CRUISING RANGE

provided three engines could get the same load into the air as four engines do. The block test curves show that below a gross load of 23,500 lb., the maximum range for three engines is increased in addition by the area added due to the steeper slope of the three-engine curve. However, a larger gross load can be lifted into the air with four engines than with three and the added reliability of the machine due to the fourth engine must be taken into consideration. The block test data appeared rather optimistic and showed a very low average consumption. It was decided, therefore, to put a blanket factor upon all average block tests and use a straight fuel consumption in flight of 0.5 per b. hp. per hr. for both three and four engine installations.

This neglects the loss in propeller efficiency of the tandem pusher in the four-engine installation, which was within the precision of the blanket fuel consumption figure assumed and the probable error due to the failure of an engine. The worst failure that might occur would be that of the center tractor, since then the center pusher propeller due to the absence of the slip-stream of the tractor propeller would be running in an air stream of a greatly decreased velocity from that for which it was designed. The failure of either outboard tractor would give a yawning moment due to the unbalanced thrust and the drag would also be added to it by the drag component of the rudders held over to keep the machine on its course in addition to the drag of the dead propeller. The "ideal" failure would be, if a failure must occur, the center pusher engine since it would not affect the steering qualities of the machine. As a matter of fact, the corkscrew rotation by a pusher slip-stream not being straightened by any body behind it, causes, in yawing to one side, the middle rudder to ride at a relative angle of incidence and gives a yawing force on the machine. This yawing force must be counteracted by a steady force on the rudder bar. In addition, as a driving unit, the pusher engine due to a lower propeller efficiency is the one that can best be spared. Using a blanket fuel consumption narrows the problem to that of being able, leaving out of consideration the damage which might be caused by the tips of the propellers failing while cutting through green water or to the hull or wings in taking off, to get into the air using four engines with a gross load which will give under the 0.5 lb. per b. hp. per hr. curve a greater area between this maximum load and that which can be lifted by three engines than that area under the curve as represented by the ordinates 16,340 and the 17,660 lb. corresponding to the weights of the two different powerplant arrangements.

The following figures based on 0.5 lb. per b. hp. per hr. show a comparison of the maximum cruising range with four engines and with three:

Engines	Maximum initial load, lb.	Range, nautical miles
4	28,000	1,420
3	25,000	1,320

TESTS AT ROCKAWAY.

Accordingly, tests were made at Rockaway to determine whether three or four engines should be used in the transatlantic flight. The NC-3, although four engines were installed, was loaded to 26,000 lb. The center tractor propeller was taken off and a proper pusher propeller put on the pusher engine. The machine failed to get off. However, with the four-engine installation operating, loaded to 28,000 lb., it got off. With this heavy wing loading, 11.8 lb. per sq. ft., the machine was handled satisfactorily in the air; therefore, aside from the added reliability the four-engine installation showed the better cruising range and was adopted. The points spotted in on the 28,000-lb. horsepower-required curve reproduced represent actual test data from runs made April 12 and 14 at Rockaway on the NC-2 with the four-engine, two-wing tandem installation.

Curves were supplied to the pilots to show at what velocities the machine should be flown to obtain the maximum cruising range under operating conditions. As the load goes off due to fuel consumed, the economical velocity of the machine must change to keep the machine at its maximum load-drag ratio which is a constant for a given machine. The angle of incidence of the wings is 8 deg. for the NC. This velocity and consequently the corresponding angle is not the same for operating conditions when there is a wind component along the course as it is in still air. These curves which are reproduced show fuel consumption plotted against velocity, the six curves covering flying loads of from 28,000 down to 16,000 lb. To obtain the economical velocities:

(1) *Still air*—From zero velocity draw a tangent to the load curve at which the machine is flying. The point of tangency gives on the horizontal velocity scale the economical velocity of the machine.

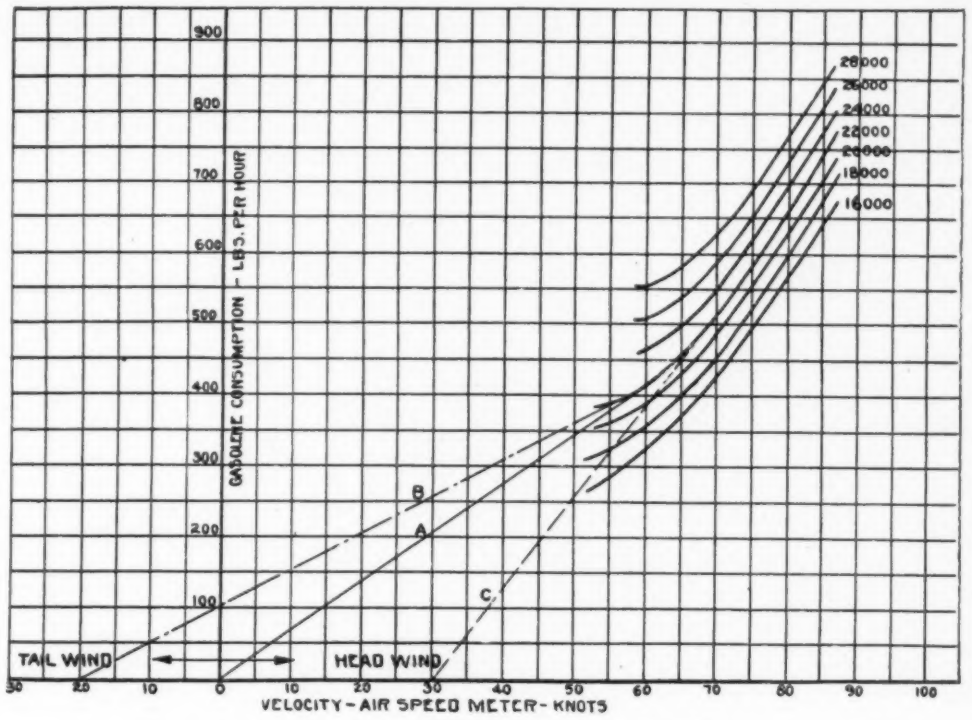
(2) *Tail wind*—From the velocity of the tail wind as read on the horizontal scale to the left of zero a tangent to the load curve will give the economical velocity, flying with that particular tail wind.

(3) *Head wind*—From the velocity of the head wind as read on the horizontal scale, to the right of zero, in the same direction as the velocities of the machine a tangent to the load curve will give the economical velocity with that particular head wind.

In the transatlantic flight the component of the surface wind along the path was communicated to the machines by the destroyers stationed along the path. This surface wind would give a good indication of what might be expected at the height at which the machines were flying.

Actual test data on the machines gave results which, within the limits of experimental error in reducing these results to the propeller efficiency condition required, were a check upon the calculated data. Therefore, the accuracy of the curves for their purpose in predicting the performance of the machines was verified.

The weights used in calculating the maximum cruising range of the machines for four and for three engines were



NAVIGATION CURVES SUPPLIED TO PILOTS OF THE NC BOATS

FOUR ENGINES, 17,660 LB.

Detailed	Lb.
Light condition	14,700
Crew, including flying equipment	1,000
Radio, telephone and telegraph set, installation and accessories	300
Water in radiators	340
Oil	1,000
Outfit and equipment	316
Total	17,656

Allowance was not made for the saving in weight due to tank weights, since the tanks were in units of 200 gal. each and whether one or two tanks could come out would depend of course on the amount of fuel that the three-engine boat could take off with.

THREE ENGINES, 16,340 LB.

Detailed	Lb.
Subtract from four-engine condition:	
Engine, bare	820
Water in engine	45
Water in radiator	50
Radiator	105
Propeller	60
Electric starter	35
Oil	200
Total	1,315

SPECIFICATION DATA.

The NC flying boat weighs when fully loaded 28,000 lb., and when empty but including radiator water and fixed instruments and equipment 15,874 lb. The useful load available for crew, supplies and fuel is, therefore, 12,126 lb., or over 43 per cent. This useful load may be put into fuel, explosives, freights, etc., in any proportion desired. For an endurance flight there would be a crew of five men, 850 lb.; radio and radio telephone, 220 lb.; food and water, signal lights, spare parts, and miscellaneous equipment, 524 lb.; oil, 750 lb., and gasoline 9,650 lb. This should suffice for a flight of 1,400 sea miles. The radio outfit is of sufficient power to communicate with ships 200 miles away. The radio telephone would be used to talk to other planes in the formation or within 25 miles.

Weight statements are always of interest to aeronautical engineers and I give below an analysis made up from the detail weights:

Weight Distribution

	Lb.	Percentage	
Tail surfaces and outriggers	1,019	6	3.6
Wings, struts, wires, fairings	4,042	25	14.4
All tanks, pipes and fittings	892	6	3.2
Four powerplants complete	4,799	30	17.2
Installation and foundations	742	5	2.7
Hull, wing floats, fixed equipment, controls, etc. (bare hull 2,800 lb.)	3,740	24	13.4
Water in radiators and engines	640	4	2.3
Weight empty	15,874	100	...
Useful load	12,126		43.2
Gross weight	28,000		100.0

Unit Weights

	Lb. per sq. ft.
Wings, including ailerons completely covered, with all fittings	1.19
Wing struts and interplane wires	0.49
Elevators, complete ready for installation	0.88
Horizontal stabilizer, complete	0.96
Rudders and fins, complete	0.91
Tail group, braced together as a biplane but not including outrigger booms to hold it in place	0.95

	Lb. per lb. displacement
Bare hull, normal displacement, 22,000 lb.	0.12
Bare hull, abnormal displacement, 28,000 lb.	0.10
	Lb. per gal.
200-gal. aluminum gasoline tank, complete with fittings and gage	0.35
91-gal. terne plate gravity tank	0.90
	Lb. per b.hp.
Radiators, empty, range between types used	0.30 to 0.38
Propeller and hub	0.24
Water for engines, including water for engine radiators and piping	0.40
Total powerplant, exclusive of foundations and structural bracing	4.00
Foundations and structural bracing	0.46

The principal dimensions and characteristics of the NC type are presented in the tabular summary on another page.

(*Concluded on page* 112)

Pulverized Coal—I*

Summary of a Report on Methods of Utilizing Otherwise Waste Coal

By Leonard C. Harvey

UNDER the auspices of the Fuel Research Board of the Department of Scientific and Industrial Research, Mr. Leonard C. Harvey, in the middle of last year, made a journey to the United States, in order to study the applications of pulverized coal to various uses in that country. On his return he made a report to the Board, which came to the conclusion that the information contained in that document would be of substantial value to the consumers of coal in British industries. It therefore published it as "Special Report No. 1," which is purchasable from agents for Government publications for the sum of 2s. 6d. net. Subsequently Mr. Harvey read before the annual meeting in May last of the Iron and Steel Institute a paper entitled "Use of Pulverized Coal, with Special Reference to its Application in Metallurgy" which was intended to form a supplement to the information contained in the report. Feeling sure that the matter will prove of interest to our readers, we propose to give in the following articles a summary of and extracts from these two documents. We may say before proceeding to do so, that both the report and the paper contain bibliographies of the subject, that in the former being the more comprehensive of the two.

At the outset it may be explained that Mr. Harvey visited twenty-three installations in which powdered coal was used commercially for, among other things, billet heating, puddling, ingot heating, tin-plating, annealing, steel, rivet heating, and reverberating melting furnaces as well as for steam boilers, cement kilns, &c. He also investigated the following systems:—The Quigley, Fuller, Holbeck, Muhlfeld, Pruden, Covert, Bergman, Aero, Kinyon, and Stroud.

The report is divided into seven chapters, and has four appendices.

In Chapter I. Mr. Harvey, after quoting an article which appeared in the Engineering Supplement of *The Times*, in February of last year, and which discussed the principles underlying the use of fuel in a pulverized form, first of all reviews in outline the several operations necessary in order to obtain a sufficient degree of pulverization of the fuel. He then considers the range of fuels suitable for use in pulverized form, referring in succession to coke, pitch, anthracite, bituminous coals, lignite, and peat.

In Chapter II. there is, first of all, a table which shows the original cost of pulverizing plants of varying sizes. It gives in parallel columns the pre-war and estimated present-day costs of plants having outputs of from 10 to 250 tons per day. For our present purpose we need only concern ourselves with the prices now ruling. It appears that a plant, with a capacity of from 10 to 40 tons per day, is estimated to cost £9,687, and will necessitate the use of one 33 in. mill. A plant capable of turning out from 50 to 90 tons per day will cost £11,562 and will require one 42-in. mill. A 100 to 130-ton plant will cost £14,062, and will need three 33-in. mills; a 140 to 180-ton plant, having two 42-in. mills, will cost £15,625; while a 190 to 250-ton plant with three 42-in. mills, will necessitate an outlay of £19,375.

As regards the cost of pulverizing the coal Mr. Harvey quotes the experience of three separate works. In the first case the possible output of the works was 80 tons and about 30 tons were actually produced. In the first case the possible output of the works was —and the output from 30 to 35 tons, while in the third the full capacity was 50 tons, and about 30 tons were produced. In case No. 1 the outgoings taken into account were for oil and grease, waste, stores and fuel for drying, labor, current at "0.02 cent."—evidently a mistake for dollars—or about 1d. per kilowatt-hour, machine shop charges, interest and taxes. The total cost, taken over a period of one month, worked out at 2.21 dols., or say 9s. 2½d. per ton. In case No. 2 the operating costs given include labor and labor insurance, stores, electric repairs, machinery repairs, engineering repairs, and electric power at 0.018 dols. No allowance was therefore made for interest and depreciation. The cost averaged over a period of six months 1.48 dols., say 6s. 2d. per ton. If, however, interest and depreciation at 14 per cent. on £11,562—the average cost of a plant to produce from 50 to 90 tons per day—be added, the total cost works out at 2.34 dols., or 9s. 9d. per ton. In case No. 3 the items taken included direct labor; repairs, labor; repairs, material; supplies, waste, &c.; insurance; and on-charges, and the total arrived at, as the average taken over a month's working, was 2.25 dols., or, say, 9s. 4½d. per ton. As a matter of fact this total was higher than it would ordinarily be because during the month there was an unusual expenditure on repairs, &c., and the normal cost is given as being more nearly 1.489 dols., or say, 6s. 2½d. per ton. Taking this lower cost the average for the first three plants works out at 2.013 dols., or just over 8s. 4½d. per ton of pulverized coal delivered to the furnaces.

The foregoing figures relate to present-day costs. For purposes of comparison Mr. Harvey gives the cost during the year 1913, and therefore before prices were influenced by the war, of a considerably larger plant, which had a full capacity of 150 tons a day, and the output of which was 140 tons per day. The costs for fuel for drying, operating, power—steam and electric—repairs to machinery, and repairs to buildings, came out at 0.602 dols., or just over 2s. 6d. per ton. Dividing 14 per cent. on the capital outlay of £10,417 by the total yearly production—42,000 tons—and adding the result to the 2s. 6d., the figure of just over 3s. 2½d. per ton is arrived at. This figure is not strictly comparable with those of the first three plants, since, whereas two of them were working very considerably below their full capacity, plant No. 4 was producing over 93 per cent. of the quantity for which it was designed. However, the items of cost, which in all cases are given in detail, will doubtless prove to be useful guides as to past and present costs in the United States under the specific conditions mentioned.

The report then goes on to outline the various processes through which the coal passes in standard mill-house practice in American installations before it becames pulverized fuel. The run of mine, lump coal or screenings, are delivered alongside the pulverizing mill in railway trucks, fitted preferably with bottom dumping doors, so that the coal may be discharged into track hoppers. From the latter the coal passes first of all to a crusher, in order that it may be broken down so as to pass through a screen of ¾ in. mesh, and is taken thence to the crushed coal bin, past a magnetic separator. From the crushed coal bin the coal descends by gravity to the dryers, which are thus referred to by Mr. Harvey:—"Dryers of several efficient types are in use. They are heated by means of hand-fired grates, mechanical stokers, or pulverized coal burners. The hot gases from the furnaces are latter case, the hot gasses first come in contact with the coal, or through a central tube to the end of the coal-drying cylinder, and thereafter returned along the outer space in contact with the coal, or again, a compromise is made between these two systems. For the latter case, the hot gases first come in contact with the outer shell of the dryer to about half-way along its length; they are then collected and transferred to the end of the cylinder where they enter into direct contact with the coal as the gases pass back through the cylinder to the furnace end, where they escape to the dryer chimney. As a rule the dryers are rated to comply closely with the maximum capacity of mills operating. Crushers are generally started up in advance of the pulverizing mill, and are run for a short time after the mills are closed down. In this way a sufficient amount of dry coal is available when the mills are started up. Coal should be dried to within one per cent. moisture, about 10 per cent. moisture being extracted at each passage of the coal through the dryer. When fuel contains a heavy percentage of water the coal can be passed through the dryer a second time." From the dryers the coal is taken to the top of the building by an elevator and delivered into the dry coal bins.

In addition to the several types of grinding mills used in cement works, the mills generally installed in American steel works are the "Fuller," the "Raymond," and the "Bonnot." The two last mentioned are ordinarily run with air separator fans. The Fuller mills have only been equipped with them comparatively recently. When they are not fixed the pulverized coal as it comes from the discharge spouts is taken up to the top of the mill-house by means of bucket elevators. The advantage of air-separation exhaust from the mills lies in the direct delivery of the coal dust to the bins without having to employ elevators. Moreover, there are the additional advantages of simplicity of plant, absence of dust leakage through crevices in the mills, and absence of dust from the elevator casing, because the elevator is non-existent, while, as a consequence, there are no repairs of the elevator to pay for. On the other hand, the total power for grinding and delivering the coal by air-separation is somewhat greater than that required to run screen mills and bucket elevators. Further than that, the coal dust must pass through the suction fan at high speed, with the result that the blades are rapidly worn, and it is necessary, moreover, to install cyclone separators to deposit the coal dust from the air current. Summing up, Mr. Harvey remarks: "With the exception of power absorbed, the advantages of one method seem almost to balance those of the other."

The standard of fineness that has been adopted throughout the United States for industrial coal dust plants is 85 per cent. through a 200 mesh screen—40,000 holes to the square inch—and 95 per cent. through a 100 mesh screen—10,000 holes to the square inch. The coal as it leaves the dryer before grinding should not contain more than 1 per cent. of moisture.

In Chapter IV. Mr. Harvey discusses the various methods of transporting the coal dust to the burner under the following headings:

(*a*) By screw conveyors.
(*b*) By the air pressure system.
(*c*) By the air mixture system.
(*d*) By the enclosed pipe cable system.

With regard to (*b*) it is explained that it was patented in 1916 by Messrs. Magarvey, Salton and Heisler, and that the process, which has been of late quite extensively adopted, is controlled by a company in New York City. In it what are called "Blowing Tanks" are installed in the mill-house. Compressed air is applied to these tanks for the purpose of forcing any given quantity of coal through small supply pipes to bins at the furnaces. The tanks are arranged on weighing platforms, so that the weight of coal delivered into them can be read off on scale dials. The coal dust travels through ordinary 3- or 4-in. screwed piping to the bins at the furnaces. In view of stoppage caused by moisture in the coal, or due to condensation within the conveying pipes, a small companion pipe with tappings into the coal delivery pipe is provided. From it compressed air can at any time be supplied through the tappings or "bleeders," as the makers have termed them, and any stoppage of coal broken up and cleared. Mr. Harvey remarks, concerning the system, that the advantages pertaining to it are considerable. By it the coal dust can be transported through relatively small pipes and normal bends, which can be led overhead or underground with just the same convenience as can water or gas pipes. An ingenious accessory to the system, designed for the semi-automatic feeding of coal dust to any number of bins throughout the works, is also discussed.

The "air mixture" method is that employed in the Holbeck patented system. In it the coal dust is mixed at the mill-house with aproximately half the quantity of air required for its complete combustion. Supply is effected at a pressure of 10-12 ounces per square inch, and a speed of 90 ft. per second through the main supply pipes to the branch service at the furnaces is reached. The main supply pipe makes a complete loop from and to the mill-house, at which point the returning coal is extracted in a cyclone separator and re-delivered to the pulverized storage bin. In cases in which long lengths of main supply piping have to be used—say, in a loop of 3,000 ft.—probably one or two booster fans would be employed.

The "enclosed pipe cable system" consists of a complete circuit of delivery pipe inside which is run a central cable fitted with discs for the conveyance of the coal dust along the supply circuit. Side outlet discharge openings controlled by shut-off valves are provided at the points wher ethe fuel is to be used. The system, Mr. Harvey explains, is only in the experimental stage, and will probably be confined to relatively short delivery distances.

*Reprinted from *The Engineer* (London.)

Rainfall and Horsepower*

To the lay mind certainly, and to the average engineer—myself included—probably the amount of horse-power which is obtainable from rainfall does not

*Communication to *The Engineer* (London).

readily suggest itself. Feeling much interest in a scheme—not yet matured—for utilizing the rainfall which takes place on the large Dartmoor tract of almost waste land in Devon, I have been making some numerical calculations with the idea of getting something more than an indefinite knowledge of what was the practical relation between rainfall and horse-power. As it is possible that these plain unvarnished calculations may be of some utility to those who have not closely studied the subject, I put them forward, though I do not claim that they possess any special features of novelty.

As a starting point let us take—

1 horse-power for 10 hours; this equals $33{,}000 \times 10 \times 60 = 19{,}800{,}000$ foot-pounds per 10 hours.

Now, 1 cubic foot of water = 62.28 lb.; therefore 1 horse-power for 10 hours $= \frac{19{,}800{,}000}{62.28} = 318{,}000$ cubic feet of water falling 1 ft. during 10 hours, or 318 cubic feet falling 1,000 ft. during 10 hours.

For one year this is

$$\frac{318 \times 365 \times 24}{10} = 278{,}500 \text{ cubic feet.}$$

Also 50 in. of rainfall—which is much below the Dartmoor average—per year is equivalent to

$2{,}323{,}200 \times 50 = 116{,}160{,}000$ cubic feet per square mile of surface; hence this would, with a fall of 1,000 ft. give

$$\frac{116{,}160{,}000}{278{,}500} = 417 \text{ horse-power.}$$

That is to say, 50 in. of rainfall per square mile for one year will, with a fall of 1,000 ft., give 400 horse-power (approximately) for 10 hours per day for one year.

Of this theoretical 400 horse-power it is probable that but about 200 horse-power could be practically utilized, owing to various losses.

In the case of Dartmoor there is plenty of area where a fall from a reservoir—of which there is room for many—to the lowlands of 1,000 ft. could be obtained.

It should be noted that in the calculation a catchment area of 1 square mile only is assumed. This is but a very small portion of the Dartmoor area at a height of 1,000 ft., which is available, and on which the rainfall would much exceed 50 in.

A reservoir of 1 square mile area and 4¼ ft. deep would contain 118,480,000 cubic feet of water, *i. e.*, sufficient with a 1,000 ft. fall to give the 400 (or 200 practical) horse-power for 10 hours per day for one year; that is to say, would hold one year's reserve. If the reservoir were, say $5 \times 4\frac{1}{4} = 21\frac{1}{4}$ ft. deep, with a total catchment area of 5 square miles, then 1,000 practical horse-power could be obtained with a one-year reserve. It would seem therefore that the amount of power constantly available would be very large.—H. R. KEMPE.

Multiple-Engined Airplanes

AT the outbreak of the war, the idea of constructing planes to be driven by two engines had been broached and discussed, detailed designs had been made for such machines and their powerplant equipment, experiments had been conducted, and at least one multiple-engined airplane, the Sikorski, had been constructed. Nevertheless, it was not until June, 1915, that information was received of the definite appearance at the front of a twin-engined German airplane. Although the Germans were thus the first to employ such a machine for active military service, they were probably anticipated as regards actual construction by the French twin-engined Caudron biplane and the British twin-engined Dyott machine. The last-named, it is interesting to note, was actually designed before the war and in many respects anticipated the design of the German Gothas of 1917. It was built in 1915, and subsequently flew successfully, although it failed to receive official approval, for some reason or other.

The three-engined airplane had also received some attention when the war broke out, notably so from the Italian Caproni, who, in 1914, built and flew a biplane equipped with two 80 h-p. tractor engines and a 90-h-p. pusher engine. Subsequently, in 1915, the same designer built a successful biplane fitted with three 150-h-p. engines. As the war progressed and the demand arose for heavy bombing machines, the twin-engined airplane took a permanent place in the aeronautical services of all the belligerents. Of these, the Gotha with two 260-h-p. engines and the Handley-Page with two 350-h-p. units may be taken as typical.

Toward the end of the war the four-engined machine had definitely appeared, and was being built in considerable numbers, in England, at least, while a five-engined German machine was brought down in France in August, 1918. Since the armistice was signed, the four-engined machine has become quite familiar, and the development of the five-engined design has progressed to the extent that there is now in existence a large British seaplane equipped with five Rolls-Royce engines which has flown successfully. We have as yet not heard anything definite about a six- or seven-engined machine, but we have Major-General Seely's authority for saying that the designs for a huge seaplane equipped with eight separate engines have been completed.

THE POWERPLANT PROBLEM.

The airplane powerplant problem at the present moment is a peculialy complicated one, and in no respect is its complexity greater than in multiple-engined machines. A very strong reason for fitting an airplane with more than one engine, at least so far as civilian flying is concerned, is, of course, the increased safety insured by so doing. With a twin-engined machine the chances of both failing before a safe landing can be effected are now very small. During the war, it may be said by way of illustrating this remark, a Handley-Page bomber as a result of a direct hit had its lower wings reduced to shreds and tatters and one of its engines put out of action; yet this machine flew back 60 miles to its airdrome, and alighted there safely. With a three-engined machine, it may be taken that all chances of having to make a forced landing as a result of engine trouble developing are eliminated. A four-engined airplane possesses the same characteristic, and with something over. Indeed, it can be asserted that as regards the avoidance of forced descents the four-engined machine possesses a factor of safety which is, or should be, satisfactory to all concerned. To increase the number of engines above four on the grounds of safety is clearly superogatory.

Setting aside such cases, if there be any, in which the multiplicity of engines is dictated by a desire to utilize existing stocks left over from the war program, it might be suggested that several small units are preferred to one or two larger units because the design and production of the former have been brought to a considerable degree of perfection, whereas the large aircraft engine possessing an equal trustworthiness has yet to be built. So far as air-cooled engines are concerned, it may be true that large units are not installed because large units are not yet available. On the other hand, the largest size at present made, we have recently seen an air-cooled engine developing 500 b. h-p., is sufficient to effect a reduction of some 25 per cent. in the number of engines fitted on the four-engined Handley-Page machine.

Water-cooled engines of 500 h-p., such as the eighteen-cylinder, three-row Sunbeam, have been manufactured in this country for some time, while engines of 1,000 h-p. are within reach of present-day production. In support of the latter assertion, it may be said that a twelve-cylinder Liberty engine has, under special conditions, developed 526 h-p., and that a twenty-four-cylinder engine of the same design has been made recently and tested with satisfactory results.

It seems clear, then, that the tendency to multiply the engine units on an airplane cannot be set down wholly to a deficiency of large powered engines. The true reason, or a large part of it, for adopting a multiplicity of engines lies, in fact, not with the aircraft engine builder, but with the makers of the airplane itself and of its propellers. The eight-engined seaplane referred to by General Seely will probably have a horse-power of nearly 3,000. Even were a thoroughly trustworthy 1,000-h-p. aeronautic engine available, it is doubtful if in the present state of the aircraft building art the designers would have chosen to do other than employ eight small engines rather than three large; for by splitting up the power between a number of units, they effect a corresponding distribution of the flying stresses in the structural parts of the machine. Further, it can be asserted that the airplane propeller capable of using 1,000 h-p. on a scale of efficiency comparable with that manifested by smaller existing propellers has yet to be designed and made. It is to be noted that, as with the marine propeller, the higher the engine speed the more difficult is it to provide a propeller which will utilize the available power efficiently, and that aeronautic engine builders are already sacrificing something to meet the shortcomings of the propeller by fitting reduction gearing on their higher speed engines. Thus the Rolls-Royce, Sunbeam, Hispano and Cosmos engines, all of which run at or over 2,000 r.p.m., are forced to employ reduction gearing, of approximately a 5 to 3 ratio, because of the present impossibility of obtaining propellers capable of utilizing the full speed economically.—*Engineer* (London).

Silk Calculations

Two old French coins were called deniers. Like the écu, the word survives in French literature just as we use the word "mite." The denier Tournoi was a small copper coin, value one-twelfth of a sou, weighing 27 Paris grains, *i. e.*, 19.6728 English grains. Two systems of calculating silk are in use, viz., the denier and the dram system. Raw silk is generally indicated by the denier system, whereas thrown silk is mostly indicated by the dram system. The legal denier in the United States is a skein of silk 450 meters long, wound in 400 turns on a reel of 112½ centimeters in circumference and weighed by a unit of 5 centigrams, known as denier. One meter equals 39.36 inches, therefore one legal denier equals 450 meters, or 492.12 yards. One lb. equals 453.6 grams, one ounce equals 566.99 legal deniers, one gram equals 20 legal deniers; hence 1 lb. equals 9,072 legal deniers. Since one legal denier equals 492.12 yards, consequently 9,072 legal deniers are equal to 4,464,513 yards. The standard of the denier varies considerably in different parts of Europe, viz.:

International, 500m—0.05 grams.
Turin, 476 m—0.05336 grams.
Milan, 476 m—0.0511 grams.
Old Lyonese, 476 m—0.05311 grams.
New Lyonese, 500 m—0.05311 grams.—*Amer. Silk Jour.*

Physical and Chemical Tests of the Commercial Marbles of the United States

THIS paper is the first report of the Bureau of Standards in connection with an extensive co-operative program for investigating the building stones of the United States. The other Government departments participating in the work on different phases of the investigation are the U. S. Geological Survey, Bureau of Mines, and Office of Public Roads.

The paper comprises the results of strength tests, water absorption, porosity, specific-gravity, freezing, thermal-expansion, electrical-conductivity and chemical tests on 552 different types of marbles produced in this country. The purpose of the work is to determine the relative value of the different types for building purposes and other special uses.

Compressive-strength tests were made on specimens in the original condition and on specimens after being soaked in water for two weeks. The dry specimens have strength values ranging from 7,850 to 50,205 lb. per sq. in. As a rule the soaked specimens gave lower compressive strengths than the dry, and in a few cases the loss due to soaking was over 25 per cent.

Transverse, and tensile-strength tests are included and show the strength of the specimens when broken perpendicular and parallel to the bedding planes.

The freezing tests made for this report consisted in determining the loss in weight and strength due to 30 freezings and thawings. While these losses were considerable in most cases, some samples showed practically no loss and occasionally a gain in strength was indicated. Hence it was decided that 30 freezings were not enough to give a trustworthy indication of the durability of such materials. An apparatus has been installed which automatically shifts the specimens back and forth between a cold chamber and warm chamber at certain intervals. With the use of this apparatus it is possible to make a great number of freezings which will correspond to several years of exposure to the weather. It is purposed to make extensive weathering tests with this apparatus to determine more definitely the relative effect of frost action on the different marbles as well as other types of building stones.

Electrical-resistivity tests were made on a number of different types to determine their relative value as insulators and resistivity under different conditions of moisture. The results show a considerable range of values, indicating that there is a choice of marble for use in switchboards and allied purposes.

Measurements of the thermal expansion made on a few samples of marble in this investigation show that this material does not expand at a uniform rate even at ordinary temperatures. As the temperature is increased the rate of expansion increases, hence it is not possible to state a coefficient of expansion for marble that will hold good for any very great range of temperatures. Another peculiarity brought out by these tests was the fact that marble when expanded by heating does not contract to its original dimensions as the temperature is lowered, but retains a part of the increase permanently. A number of successive heatings show the same effect, each adding an increment of length to the specimen.

A few cases of warped marble slabs are illustrated and a discussion is made of the causes which may be instrumental in bringing about this warping. (Abstract from Bureau of Standards Technologic Paper No. 123.)—*Mechan. Engineering.*

Progress in Naval Aircraft

(*Concluded from page 109*)

Summary of the NC Type.

Type engines	Liberty
Number of engines	4
Power, hp.	1,600
Span, upper, ft.	126
Span, lower, ft.	94
Length, ft. in.	68—5½
Height, ft. in.	24—5⅛
Chord, ft.	12
Gap, ft.	13½ to 12
Wing curve	R. A. F. 6
Angle of wings to hull, deg.	3
Angle of engines to hull, deg.	0
Angle of stabilizer to hull, deg.	2
Upper dihedral angle, deg.	0
Lower dihedral angle, deg.	3
Wing area, including ailerons, sq. ft.	2,380
Aileron area, sq. ft.	265
Stabilizer area, sq. ft.	268
Rudder area, sq. ft.	69
Elevator area, sq. ft.	240
Fin area, sq. ft.	79
Weight empty, lb.	15,874
Weight loaded, lb.	28,000
Useful load, lb.	12.126
Capacity of gravity tank, gal.	91
Capacity of fuel tanks, gal.	1,800
Capacity of oil tanks, gal.	160
Maximum speed at 28,000 lb., knots	74
Minimum speed at 28,000 lb., knots	58
Maximum speed at 24,000 lb., knots	84
Minimum speed at 24,000 lb., knots	55
Center of gravity	35 to 45 per cent of wing chord
Factor of safety for 28,000 lb.	3

* * *

In short, the NC design is an all-American proposition like the Liberty Engine. It represents the organized result of what we had learned from previous experience, what we could deduce as to the future by application of aeronautical engineering theory and methods and what we could learn from foreign practice.[1]

Evolution and Sexuality

(*Concluded from page 103*)

tinues to proceed without the aid of sex. Those organisms which multiply by division or by parthenogenesis vary and their variations become hereditary; when a sexed condition involves a crossing it adds a new possibility of variation, but it is not the sole cause of variation.

* * *

At present the phenomenon of sex presents itself to us as the result of the reactions which have taken place and are taking place at certain times between living organisms and external influences. These results having been obtained the differentiated organisms have been able to continue to live, not because the sexed state procured for them the slightest advantage in itself, but rather in spite of the disturbance which it sometimes occasioned. In all these cases it proved not to be injurious—or if it were so for some organisms the latter disappeared in consequence. All we know at the present time are those forms in which sex was not inevitably incompatible with existence—these have persisted, since selection, as I intend to demonstrate at a later date, suppresses only those forms worst fitted for the struggle of life.

Monel Metal in Turbine Blades

THE accompanying article on the properties of Monel metal (page 98) lays great stress on the advantages and virtues of this alloy; but does not fully consider some important points that may be made against it. In the interest of a better rounded consideration of the subject the editor here reprints some remarks made by the Editor of "Power" (New York) in this connection.

"Monel metal does make an excellent material for service as turbine blades; but most builders, because of the expense, do not use it for turbines to the extent that might be inferred from the article. Nearly all builders agree that there is slight difference between the wearing qualities of a good nickel steel and monel metal. However, from a shop viewpoint, the chief disadvantage of the latter is that it is severe on dies and increases die charges. One of the largest builders of steam turbines in this country has never used monel for the blades except for one small single-wheel impulse machine in which the steam velocities are exceedingly high. This builder doubts that monel is as good for high-speed blades as pure nickel, which is now available. Great physical strength in the high-pressure blading in modern turbines is not vital. For the sake of efficiency all such blading, whether impulse or reaction, should operate at slow speeds, which result in low mechanical stresses. For the exhaust end blading where these stresses are high low-carbon, nickel, electric-furnace steel is widely used."

[1]Extensive credit is given, but here omitted for lack of space.—EDITOR.

New Case-Hardening Process

A NEW process has been brought out by Porter W. Shimer, Easton, Pa., for case-hardening steel. Prof. Joseph W. Richards, Lehigh University, Bethlehem, Pa., in describing this new method in a paper presented at the New York meeting of the American Institute of Mining Engineers explained that there are two essentially different types of case-hardening processes. There is the one using a dry mixture in which the object is packed and kept for the necessary time at the necessary temperature, and the other the liquid process employing a bath of fused salts into which the object is immersed and which by immediate contact case-hardens the surface of the article.

The Shimer process belongs to the latter class. It involves the use of a substitute for the bath of melted cyanides which it is claimed case-hardens with equal or greater facility and effectiveness, gives off no poisonous vapors and costs for chemicals but a fraction what the cyanide costs in the previously used baths. The process has been in use over a year in a large American works. The following statement embodies the results of practical experience in the use and operation of the process:

The Shimer liquid or melted bath consists of a mixture of easily fusible salts that do not possess case-hardening properties, into which is immersed fresh calcium cyanamide, which imparts to the bath case-hardening properties. The composition of the non-case-hardening salts appears rather immaterial. Good results have been obtained by using a mixture of sodium chloride, calcium chloride and barium chloride in equal proportions by weight; also a mixture of one part sodium chloride to one part calcium chloride. Potassium chloride can replace the sodium chloride where the question of cost is not material, producing a very liquid bath when equal chemical parts of the two salts are used; that is, 58.5 parts of sodium chloride to 75.5 parts of potassium chloride. Alkaline carbonates or alkaline hydroxides have also been added to the bath material with advantage in some special cases.

The mixture of non-case-hardening salts is melted in an iron or steel pot suitable for case-hardening operations, and the calcium cyanamide is brought into contact with it, which may be accomplished in several ways. One very effective method is to place small lumps of the cyanamide in an iron basket, which is sunk to the bottom of the case-hardening pot. A lively evolution of gas soon takes place, the exact composition of which has not yet been fully determined. The bath quickly acquires case-hardening properties, which last as long as the evolution of gas continues. What the exact chemical reaction of the cyanamide upon the non-case-hardening salts is, to produce a melt that has excellent case-hardening properties, has not yet been determined; it would need thorough and arduous chemical investigation to precisely illuminate the rationale of the operation. The fact remains, however, that contact of the cyanamide with the other salts imparts to the liquid bath active case-hardening properties.

In practice, the calcium cyanamide is immersed in the bath of melted salts and as soon as a lively evolution of gas is shown, the dipping in of articles and their case-hardening can be proceeded with. If the evolution of gas becomes too active, the cyanamide may be removed and case-hardening can be proceeded with for some time after this removal. When the case-hardening power of the bath decreases, the cyanamide may be re-immersed and the operation continued as before. If the cyanamide is in large fresh pieces and the evolution of gas is not too violent, the cyanamide may be left permanently in the bath until it has lost its power of imparting case-hardening properties to the melt, as is shown by the diminution of the evolution of gas. On removing this apparently exhausted material, the larger pieces may be broken, thus exposing fresh surfaces, and the material will be found to still retain active properties when re-immersed in the bath.

It has been found that the cyanamide is best used in lumps varying from the size of a walnut to the size of an egg. It should be in the fresh condition as it is taken from the furnace; that is, it should be kept hermetically sealed until used. If fine powder is put into the bath, it is difficult to keep the powder immersed, and the frothing is voluminous and troublesome. If the cyanamide has been exposed to air, absorbing moisture and becoming oxidized, it causes violent frothing when immersed in the bath, which continues an inconveniently long time. If only such cyanamide is available it may be mixed with pulverized hard pitch or with tar, and the mass coked at a red heat; this eliminates absorbed moisture and changes the structure from powder to a porous coke. Such porous cake is then used in the melted salts in exactly the way that has been described for solid lumps of fresh calcium cyanamide. Arrangements have been made with the manufacturers of calcium cyanamide to select high-grade cyanamide for the purposes of this process, and to transfer it directly from the furnace in lumps of desired size to air-tight containers, so that its use in the process will always be at a maximum efficiency.

The quantity of cyanamide immersed may vary according to the size of the bath and the shape, size and character of the articles to be case-hardened. A bath may have immersed in it 5 per cent. of its weight of the fresh calcium cyanamide, or a corresponding quantity of the cyanamide coke, for ordinary work. Upon removal from the bath, the case-hardened articles are quenched in a suitable cooling liquid as in ordinary case-hardening practice.

A careful estimate of the relative cost of running with the sodium cyanide at normal market prices and calcium cyanamide as described, extending over more than a month's work in a large plant, shows the cost of the bath material to be approximately one-fifth as much when using calcium cyanamide as when using sodium cyanide, with the case-hardening done in an equally satisfactory manner, and with much more comfortable and healthful conditions to the workmen. The question of the scientific basis of the process is being investigated by the inventor.—*Iron Age.*

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